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EFFECTIVENESS OF SELECTING FOR RAPID AND FOR SLOW GROWTH RATE IN HAMPSHIRE SWINE[1]

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Introduction

SWINE breeders have been influenced, consciously or unconsciously, by growth rate in attempting to improve their hogs. This attention to growth rate is justified by the shorter feeding period and by the smaller feed requirement generally associated with an increase in growth rate. The effectiveness of such selection depends largely upon the extent to which the observed differences in growth rate are actually heritable, in the sense that the offspring will exhibit part of the superiority or inferiority in growth rate which their parents exhibited. Many estimates of heritability have been made from studies of the association between growth rates of parents and their offspring. In certain breeding experiments with both plants and animals the actual cumulative effects of selection over a number of generations have been measured to determine how much of the change resulting from selection is permanent. A classic selection experiment of this kind is the one on the composition of corn conducted by Winter (1929) and analyzed further by "Student" (1934). Similar studies have been reported for egg production in poultry by Marble and Hall (1931), for body size in mice by Goodale (1938) and by MacArthur (1944), for food consumption and utilization in the rat by Morris *et al.* (1933), and for feed utilization in swine by Grimes (1941). This paper reports the results of selecting for rapid growth in one line and slow growth in another line of Hampshire swine fed at the Illinois Station during four generations, in a project which is cooperative with the Regional Swine Breeding Laboratory.

Review of Literature

Previous studies of the association between certain relatives for growth rate in swine indicate that the heritable portion of individual differences in weight is small at birth but increases steadily with age and reaches a maximum of one-fourth to one-third at five to six months of age. Lush *et al.* (1934) estimated the heritability of birth weight to be six percent. For weaning weight, Bywaters (1937) obtained an intra-sire regression of progeny on

[1] This investigation was conducted in cooperation with the Regional Swine Breeding Laboratory, Ames, Iowa, Bureau of Animal Industry, U. S. Department of Agriculture.

[2] We gratefully acknowledge the assistance and excellent suggestions of Dr. G. E. Dickerson, Geneticist, Regional Swine Breeding Laboratory. We are also indebted to Miss M. E. Gregory for assistance in the statistical analysis of the data, and to R. H. McDade, Chief Swine Herdsman, whose interest at the farm added materially to the experiment.

dam of .077 and found a correlation between paternal half-sibs of .017, from which heritability may be calculated as 15 and 7 percent, respectively. Comstock *et al.* (1942), using intra-sire regression, obtained estimates of heritability of 0 for weaning weight and 14 percent for 180 day weight. From an analysis of variation due to sire and line differences, Baker *et al.* (1943) estimated the heritability of weight at birth, 21, 56, 84, 112, 140, and 168 days to be 0, 4, 15, 26, 28, 19, and 25 percent, respectively. A similar analysis of growth data on Landrace and Chester White swine by Hetzer (1942) gave heritability estimates for weight at birth, 21, 56, 98, 140, and 182 days of 16, 10, 0, 33, 39, and 24 percent, respectively.

A recent study based on the variation due to sire differences within partially inbred lines by Nordskog *et al.* (1944) yielded heritability estimates for weight at different ages of 0 at 112 days or earlier, and 21 and 27 percent at 140 and 168 days, respectively. Similar estimates for rate of gain from birth, and from weaning, to 200 pounds were, respectively, 21 and 40 percent.

For weight at 180 days, Whatley (1942) concludes that heritability was at least 30 and perhaps 40 percent in his study of data on Poland Chinas. His lowest estimate of 20 percent was based on the fraction of the variation arising from differences among sires and his highest estimate of 62 percent was obtained from the intra-sire regression of progeny on dam. By averaging results from these same two methods, Whatley and Nelson (1942), using data on Duroc Jerseys, calculated the heritability of 180-day weight at 23 percent.

From weaning to 200 pounds the heritability of rate of gain has been calculated at 24 percent by Lush (1936) using Danish progeny testing data. In similar Norwegian pig testing data, Berge (1936) found that the portion of the total variation in rate of gain accounted for by differences in the sires was 13 percent for Yorkshires and 5 percent for Landrace. These values correspond to heritabilities of 52 and 20 percent, respectively.

Since the present study concerns weight for age, rough averages of all heritability percentages found in the literature may be useful for comparison. The percentages average about 6 for weights from birth to weaning, 14 for weights at 84 and 112 days, and 25 for weights at 168 or 180 days.

Plan of Experiment

From a representative population of Hampshire swine, selection for a rapid-growing line and for a slow-growing line has been in progress through four generations. The foundation animals of the two lines were selected on the basis of weight at 180 days of age from 41 head of Hampshire boar pigs and 42 head of Hampshire gilts. These pigs were purchased as weanlings from the 1939 spring farrow of 48 Illinois Hampshire herds and were all fed

subsequently at the Illinois Station. The 5 boars and the 15 gilts which gained most rapidly, and a like number of the slowest gaining boars and gilts comprised the two foundation herds. Since their inception, the two lines have been carried as closed herds. By using 5 boars in each line, saving only one boar from a litter, and by mating each boar to the gilts least related to him, inbreeding has been kept at a low level. In the fourth generation, the average inbreeding calculated by Wright's (1922) formula was 4.4 percent for the slow-gaining line and 4.1 percent for the rapid-gaining line. All litters of both lines were farrowed by gilts and sired by boars of approximately the same age as the gilts. The pigs were weighed individually at birth, 21, 56, 150 and 180 days of age. Selections were based on 180-day weights in 1939, 1940 and 1941, and on 150-day weights in 1942 and 1943. A progress report was made by Fairbanks, Roberts and Carroll (1943) covering the first three generations.

Results

This study includes the records of 749 pigs from 98 spring litters sired by 41 boars during a four-year period. Since the purpose of this study was to measure the cumulative effect of selection based on rate of growth over several generations, this phase of the results will be considered first. The data also permit the usual estimates of heritability based on the association between parent and offspring.

Line Differences Resulting from Selection

The mean weights at each age are given in table 1 for all progeny of each line and generation. After weaning, the boar pigs grew a little faster than the gilts. The mean sex difference within the 8 line-generation progenies was 3.4 pounds at 150 days, and 4.7 pounds at 180 days, but only .06 pounds at 56 days. The selection practiced in each generation and line is shown in table 2 by the average superiority or inferiority of the parents compared with the whole population from which they were selected. Although selection for weight at 150 and 180 days averaged more than twice as great for sires as for dams, it was nearly the same in the slow line as it was in the rapid line. The mean superiority in growth rate of rapid-line progeny over slow-line progeny in each generation is an estimate of the genetic difference which has accumulated as a direct result of all prior selection for opposite extremes of growth rate. The results for weight at 180 days are presented graphically in figure 1.

Part of the effect of selection in a parent generation on progeny in the generation immediately following may be due to the favorable or unfavorable effects of certain gene combinations which are broken up, and thus lose their

TABLE 1. MEAN WEIGHTS AT DIFFERENT AGES FOR ALL PROGENY BY LINES AND GENERATIONS

Age when weighed	Line[1]	Generation 0		1		2		3		4	
		No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean
			lbs.		lbs.		lbs.		lbs.		lbs.
Birth	R	—	—[2]	104	2.54	82	2.53	93	2.66	116	2.72
	S	—	—	114	2.44	85	2.45	86	2.65	69	2.52
	R-S	—	—	—	0.10	—	0.08	—	0.01	—	0.20
21 days	R	—	—	77	8.84	55	10.10	67	10.49	—	—[3]
	S	—	—	66	9.20	70	9.70	59	10.00	—	—
	R-S	—	—	—	−0.36	—	0.40	—	0.49	—	—
56 days	R	—	—	67	24.97	51	25.70	64	24.80	66	22.86
	S	—	—	65	25.83	69	24.40	54	22.50	24	18.67
	R-S	—	—	—	−0.86	—	1.30	—	2.30	—	4.19*
150 days	R	79	105.4	65	103.3	50	118.2	50	100.0	41	91.7
	S			60	95.7	67	110.8	47	75.4	11	76.5
	R-S			—	7.6	—	7.4	—	24.6**	—	15.2*
180 days	R	79	142.0	65	140.8	50	161.1	50	139.9	41	129.2
	S			60	126.8	67	151.6	47	107.6	11	106.5
	R-S			—	14.0**	—	9.5*	—	32.3**	—	22.7**

* $P \leq .05$, ** $P \leq .01$.

[1] R = rapid-gaining line; S = slow-gaining line; R − S = mean difference (rapid minus slow).

[2] The pigs from which the parents of the first generation were selected were weighed only at 150 and at 180 days.

[3] Twenty-one-day weights were not taken in the 4th generation.

influence in later generations. If such temporary effects of selection are important, the cumulative effectiveness of selection over several generations will be less than that indicated by the line difference in the first generation and less than would be expected from the usual studies of the intra-sire regression of progeny on dam or of the intra-line variation due to differences between sires.

The heritable portion of the differences in weight for age among individuals of the same line is shown in A of table 3 for each generation. Estimates are given only for weight at 150 and 180 days, because selections were based on weights at these ages. The first generation line difference indicated that differences in 150- and 180-day weights were 22 and 27 percent heritable, respectively. However, the lower heritability indicated by the line differences in later generations suggests that part of the response to selection was temporary. Yearly differences in environment are probably largely responsible for the irregularity of the increase in size of the line difference

TABLE 2. MEAN SUPERIORITY OR INFERIORITY OF SELECTED PARENTS, IN WEIGHT FOR AGE (POUNDS)[1]

Age when weighed	Sex	Line	Parents of generation			
			1	2	3	4
Birth	Sires	Rapid	—	.20	.32	.33
		Slow	—	−.08	.30	−.37
	Dams	Rapid	—	.20	.14	.15
		Slow	—	−.07	−.08	−.05
	All parents	Rapid	—	.20	.23	.24
		Slow	—	−.075	.11	−.21
21 days	Sires	Rapid	—	1.12	1.26	1.28
		Slow	—	−2.36	−.92	−1.35
	Dams	Rapid	—	.03	.93	1.36
		Slow	—	−1.29	−.52	.01
	All parents	Rapid	—	.58	1.10	1.32
		Slow	—	−1.82	−.72	−.67
56 days	Sires	Rapid	—	3.82	4.67	7.92
		Slow	—	−4.56	−2.75	−3.29
	Dams	Rapid	—	−.25	2.16	4.24
		Slow	—	−3.96	−2.09	−.50
	All parents	Rapid	—	1.78	3.42	6.08
		Slow	—	−4.26	−2.42	−1.90
150 days	Sires	Rapid	23.4	18.7	14.8	42.3
		Slow	−18.3	−24.7	−43.2	−21.5
	Dams	Rapid	14.6	11.3	9.7	12.6
		Slow	−11.6	−19.2	− 6.2	− 8.9
	All parents	Rapid	19.0	15.0	12.3	27.5
		Slow	−15.0	−22.0	−24.7	−15.2
180 days	Sires	Rapid	36.4	20.7	18.4	43.3
		Slow	−32.8	−24.2	−52.6	−24.5
	Dams	Rapid	17.6	9.6	13.2	12.3
		Slow	−15.6	−20.0	− 9.8	−10.3
	All parents	Rapid	27.0	15.1	15.8	27.8
		Slow	−24.2	−22.1	−31.2	−17.4

[1] In calculating the mean of the parents of each generation, each parent is weighted according to its number of progeny. The mean for the whole population from which parents were selected is then subtracted from the mean for selected parents to obtain the average superiority or inferiority of parents.

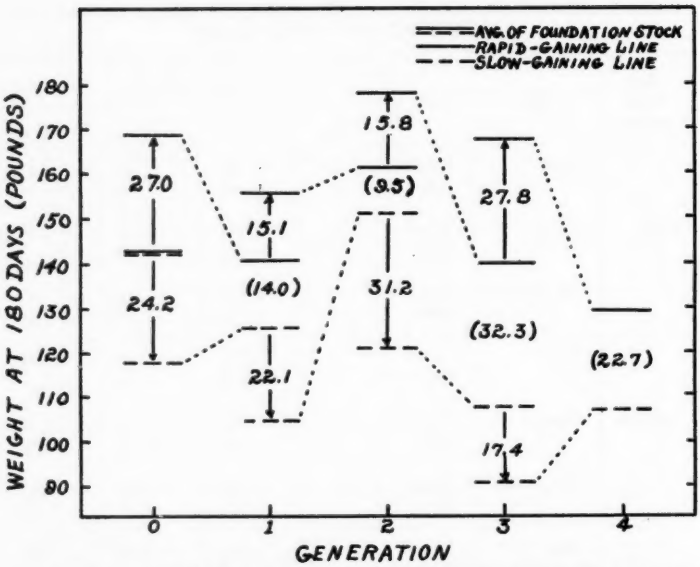

Figure 1. Chart showing the amount of selection (in opposite directions) of parents of rapid and slow-gaining lines, and the weight at 180 days of all offspring and of those selected for breeding in four subsequent generations. Average differences between the progeny of the two lines in each generation are shown in parentheses.

(table 1, figure 1). The difference was small the most favorable year (generation 2) and again in generation 4, when death losses were much higher in the slow line than in the rapid line. This would presumably eliminate the slowest gaining pigs in the slow-line and thus narrow the mean difference in growth rate between survivors in the two lines. The averages of the four estimates for heritability of intra-line differences are 16 and 19 percent for 150- and 180-day weights, respectively (A, table 3). These are probably as reliable estimates as can be obtained from the first four generations of this experiment.

The line difference, and hence any heritability estimate derived from it, was statistically significant in all generations for 180-day weight, in generations 3 and 4 for 150-day weight, only in generation 4 for 56-day weight, but in no case for weight at birth and 21 days. Heritability estimates were not calculated from the line differences in weight at birth, 21 or 56 days because selection was based on weight at 150 and 180 days. A pig's heredity affects rate of growth similarly at different ages but is indicated most accurately by

weights taken several months after weaning (Hazel *et al.*, 1943). Therefore, the selection on weight at 150 or 180 days of age might be expected to produce larger line differences in weight at the earlier ages than would have resulted from selecting directly for weight at these ages.

The proportion of the difference in growth rate between parents of the two lines which is heritable (B and C, table 3) tends to increase with additional generations of selection because an increasing proportion of the parental difference is represented by the line difference which has accumulated from selection in earlier generations (figure 1).

TABLE 3. HERITABILITY OF WEIGHT FOR AGE ESTIMATED FROM THE LINE DIFFERENCES RESULTING FROM SELECTION

Item studied	Generation	Percentage heritability for weight at	
		150 days	180 days
A. For differences in weight between pigs of same line[1]	1	22.4	27.4**
	2	10.4	10.8*
	3	22.8**	23.8**
	4	10.1*	12.6**
	Av.	16.4	18.6
B. Differences in weight between pigs of different lines[2]	1	22.4	27.4**
	2	16.6	18.6*
	3	55.2**	57.1**
	4	22.4*	29.1**
C. Excess of *B* over *A* (largely due to the genetic difference between lines, which has accrued from selection in previous generations)	1	0.0	0.0
	2	6.2	7.8
	3	32.4	33.2
	4	12.3	16.6

* $P \leq .05$, ** $P \leq .01$.

[1] Intra-line heritability for each generation is estimated by dividing the mean difference between unselected progeny of the two lines by the total amount of selection contributing to that line difference (tables 1 and 2, figure 1). For example, the mean 180-day weight for 3rd generation pigs was 32.3 pounds heavier for the rapid than for the slow line. For the first 3 generations the superiority of rapid line parents selected over the population from which they came was 27.0, 15.1, and 15.8 pounds and the inferiority of the slow line parents under the population from which they came was −24.2, −22.1, and −31.2 pounds which is equivalent to an intra-line difference of 135.4 pounds between rapid and slow line parents of the 3rd generation. Thus heritability is estimated as $\frac{32.3}{135.4} \times 100 = 23.8$ percent.

[2] Inter-line heritability is estimated for each generation by dividing the mean difference for unselected progeny of the two lines by the difference between the means of their parents. In 180-day weight, for example, parents of the third generation averaged 161.1 + 15.8 = 176.9 for the rapid line and 151.6 − 31.2 = 120.4 for the slow line (tables 1 and 2, figure 1). Third generation progeny were 32.3 pounds heavier in the rapid than in the slow line. Thus 57 percent (i.e. $\frac{32.3}{56.5} \times 100$) of the difference between parental means in the third generation is estimated as heritable.

Differences between Sire Progenies within Lines

The proportion of the variation due to differences between sire progenies (or the correlation between members of the same sire progeny) has been used commonly as one basis for estimating heritability of various characteristics in animals. This type of analysis was applied to these data, which include 41 sire progenies. The data were analyzed within years and lines so the evi-

TABLE 4. ANALYSIS OF VARIANCE FOR WEIGHT AT FIVE AGES

Source of variation	Birth		21 days[1]		56 days		150 days		180 days	
	D/F	Mean square	D/F	Mean square	D/F	Mean square	D/F	Mean square	D/F	Mean square
Total	748	.268	394	4.22	459		390		390	
Between lines	1	2.160	1	.79	1	74.73	1	7,757[3]	1	17,856[3]
Between years	3	1.622	2	57.61[2]	3	271.87	3	14,469[3]	3	22,034[3]
Lines×years	3	.112	2	7.58	3	154.55	3	4,080[2]	3	6,952[3]
Between sires within years and lines	33	1.109	27	14.08	33	114.87	32	1,040	32	1,231
Between litters within sires	57	.974[3]	34	10.73[3]	49	88.92[3]	46	813[3]	46	852[3]
Between litter mates	651	.155	328	2.40	370	23.51	305	302	305	400

D/F = degrees of freedom.
[1] Twenty-one day weights were not taken in 1943.
[2] $P \leq 0.05$, significant.
[3] $P \leq 0.01$, highly significant.

dence obtained on the heritability of weight at different ages would apply to differences among pigs of the same line and season.

The mean squares from the analysis of variance (Snedecor, 1940) are given in table 4. In weight at 150 and 180 days of age, the line differences varied significantly from year to year, due partly to the steadily increasing line difference with additional years of selection in opposite directions and partly to the more nearly random yearly fluctuations in environment, including disease. The average difference between lines for weight at 150 and 180 days was highly significant as compared with sire differences within lines. Differences between litters by the same sire were highly significant at all ages. Differences between sire progenies were as much larger than those between litters by the same sire, as could be reasonably expected for a trait influenced as much by environment as is growth rate. However, larger numbers would have been necessary for the sire differences to be statistically significant. Consequently, none of the heritability estimates derived from these sire differences will differ significantly from zero. However, they will

be more reliable as an indication of the relative, than of the absolute heritability of weight at the various ages, because the same sire progenies were represented at all ages.

The mean squared deviation or variance from heritable differences among sires (S), from differences between litters of the same sire (D), and from differences between litter mates (A) may be estimated from the mean squares in table 4. It is only necessary to calculate the average number of times the variance from each source is represented in a given mean square, as illustrated in table 5. The estimates of the variances A, D, and S are presented in table 6 for weight at the five ages.

TABLE 5. THEORETICAL COMPOSITION OF MEAN SQUARES[1]

Source	D/F	Composition of Mean Squares[2]
Between sires within years and lines	$N_s - N_{yo}$	$A+\bar{d}'D+\bar{s}S$, $\bar{d}'=\left[\frac{\Sigma\left(\frac{\Sigma d^2}{\Sigma d}\right)_s - \Sigma\left(\frac{\Sigma d^2}{\Sigma d}\right)_{gy}}{N_s - N_{gy}}\right]$, $\bar{s}=\left[\frac{N-\Sigma\left(\frac{\Sigma s^2}{\Sigma s}\right)_{gy}}{N_s - N_{gy}}\right]$
Between litters	$N_d - N_s$	$A+\bar{d}D$, $\bar{d}=\left[\frac{N-\Sigma\left(\frac{\Sigma d^2}{\Sigma d}\right)_s}{N_d - N_s}\right]$
Between litter mates	$N-N_d$	A

[1] Where: N = total number of pigs
N_d = total number of litters
N_s = total number of sire progenies
N_{gy} = number of line-year groups
d = number of pigs in a litter
s = number of pigs in a sire's progeny
subscript s = for a sire progeny
subscript gy = for a line-year group
A = intra-litter variance
D = litter variance
S = sire variance

For example, in a 180-day weight:

$$A = 400$$

$$D = \frac{852 - 400}{\bar{d}} = 107.93, \text{ when } \bar{d} = 4.188$$

$$S = \frac{1231 - 400 - \bar{d}'D}{\bar{s}} = 32.34, \text{ when } \bar{d}' = 4.891 \text{ and } \bar{s} = 9.373$$

[2] Formulas supplied by Dr. G. E. Dickerson, Geneticist, Regional Swine Breeding Laboratory.

The total variance among pigs within the same line and year but by different sires and dams is $A+D+S$. The fraction of this total which is

TABLE 6. THE ESTIMATES OF A, D, AND S FOR WEIGHT AT FIVE AGES

Age (days)	Source of variance			
	A	D	S	A+D+S
Birth	.155	.112	.003	.270
21	2.40	1.47	.25	4.12
56	23.51	13.94	1.32	38.77
150	302.00	122.02	15.07	439.09
180	400.00	107.93	32.34	540.27

heritable is estimated as $4S/A+D+S$, since heritable variation among offspring arises approximately $\frac{1}{4}$ from differences among their sires, $\frac{1}{4}$ from differences among their dams and $\frac{1}{2}$ from chance in the segregation and recombination of gametes. This fraction is an estimate of the proportion of the superiority of parents over the average of their generation which is heritable and will be transmitted to their immediate offspring, *i.e.* regression of transmitting ability (G) on performance (P) is $b_{GP}=r_{GP}\cdot\frac{\sigma_G}{\sigma_P}=\frac{\sigma_G^2}{\sigma_P^2}=\frac{4S}{A+D+S}$.

The excess of D over S is an estimate of the variance from litter differences in environment and in non-heritable genetic effects (nicking) of certain sire-dam combinations. $A-2S$ is an estimate of the variance from non-heritable (mostly environmental) differences between litter mates.

The estimates of the percentages of the variance within line and year due to heredity and to non-heritable differences between litters and among litter mates are given in table 7. Except for weight at 21 days, the percentage of variance in weight attributed to heritable differences increases steadily

TABLE 7. THE PERCENT OF VARIANCE IN WEIGHT ATTRIBUTED TO HERITABLE DIFFERENCES AND TO NON-HERITABLE VARIATION BETWEEN AND WITHIN LITTERS

Age (days)	Heritable differences $\frac{(100)\,4S}{A+D+S}$	Non-heritable differences	
		Between litters $\frac{(100)(D-S)}{A+D+S}$	Within litters $\frac{(100)(A-2S)}{A+D+S}$
Birth	4.6	40.3	55.1
21	24.0*	39.7	46.3
56	13.6	32.6	53.8
150	13.7	24.4	61.9
180	23.9	14.0	62.1

* 21-day weights not taken for the 4th generation pigs.

from 5 at birth to 24 at 180 days. The discrepant estimate of 24 percent for weight at 21 days is probably due, in part, to the fact that 21-day weights were not obtained on the fourth generation pigs. The importance of litter environment decreases from 40 percent at birth to 14 percent at 180 days, while non-heritable variation among litter mates accounts for 46 to 62 percent of the variation in weight at all ages.

Regression of Offspring on Dam

All pairs of dams and their litters were used to calculate intra-sire regressions of offspring on dam by the method described by Lush (1940). In these data, intra-sire also means within groups of litters, each of which was farrowed in a single season and was out of dams farrowed in the same season of the preceding year.

This method gave overestimates of heritability for weight at all five ages and the estimates were higher for weight at 21 and 56 days than at 150 and 180 days. These results suggest some sort of a direct relationship between growth rate of dam and progeny, in addition to the hereditary growth-factors transmitted. Since progeny-dam regression has been widely used for estimating heritability, further studies are being made in an atempt to discover what factors were responsible for the overestimates obtained from our data. Whatley (1942) also obtained a much higher estimate of heritability for 180-day weight from progeny-dam regression than from the other methods he used. His estimate of 62 percent for 180-day weight is in fair agreement with the estimate of 65 percent obtained from these data. Both values are obviously too high.

Discussion

The evidence from this selection experiment indicates that differences in weight at 5 or 6 months of age among pigs farrowed in the same season and line of breeding are about $\frac{1}{6}$ or $\frac{1}{8}$ heritable. This means, for example, that if the sires and dams of a generation of progeny averaged 30 pounds heavier at 180 days of age than the whole population from which they were selected, the resulting improvement among their descendants would be about 5 or 6 pounds, although the effect on the immediate progeny of the selected parents might be somewhat greater. This estimate corresponds to the lower limits of other heritability estimates based on studies of the association between relatives.

The present results (table 7) support the findings of Baker *et al.* (1943), Comstock *et al.* (1942), and Nordskog *et al.* (1944) that the heritability of weight for age increases steadily with age, while the influence of litter (maternal) environment decreases. Our heritability estimates are higher for

180-day than for 150-day weight, from two methods, i.e. from line differences resulting from selection (table 3) and from the analysis of variance (table 7). Baker *et al.* (1943) and Nordskog *et al.* (1944) obtained similar results. In addition to being more highly heritable, 180-day weight represents growth rate up to market weight more nearly than 150-day weight, and therefore would seem preferable as a measure of growth rate in the selection of breeding stock. Nevertheless, ranting in boars and certain other factors may make it desirable to use weight at an earlier age, i.e. 150 or 154 days.

Summary and Conclusions

The results of selecting for rapid growth in one line and for slow growth in another line of Hampshire swine during four generations are presented. A total of 749 pigs from 98 spring litters and by 41 boars were farrowed during the four generation period. The effectiveness of selection for, or heritability of, growth rate was estimated (1) directly from the line differences resulting from the selection practiced, and (2) indirectly from the portion of the variance within line and year due to heritable differences between sires. The pigs were weighed at birth, 21, 56, 150 and 180 days of age. Selections were based on weight at 150 and 180 days.

The line differences resulting from selections for either rapid or slow growth rate at 5 or 6 months of age were $\frac{1}{8}$ to $\frac{1}{5}$ as large as they would have been if the differences in growth rate were completely heritable. This estimate is less than indicated by the results obtained in the first generation, and corresponds to the lower limits of heritability estimates, reported in the literature, which were based on studies of the association between relatives.

Analysis of variance within lines and years indicated that heritable differences in weight increased steadily from 5 percent at birth to 24 percent at 180 days, whereas the percentage of the variance due to non-heritable differences between litters decreased from 40 at birth to 14 at 180 days. The non-heritable variation among litter mates accounted for 46 to 62 percent of the variance in weight at all ages.

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HYBRID VIGOR IN SINGLE CROSSES BETWEEN INBRED LINES OF POLAND CHINA SWINE[1]

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Introduction

TWELVE inbred lines of Poland China swine have been developed at the Iowa Agricultural Experiment Station as part of the work of the Regional Swine Breeding Laboratory. Some of these lines are inter-related, 6 having been separated in 1937 from a single 4-sire line established in 1930. The remaining 6 lines were established in 1937 and 1938; 4 of these were unrelated to each other or to the first 6 lines; 2 were each formed by crossing the foundation stock from a different pair of unrelated lines among the other 10. Of the 12 lines, 8 have been maintained as 1-sire lines, 3 as 2-sire lines and 1 as a 4-sire line. By 1942, the average inbreeding of the lines ranged from 50 to 20 percent.

A comparison of single crosses with inbreds was obtained from the fall litters in 1942 and 1943. The primary purpose was to measure the effect of the inbreeding of the pigs on their viability, rate of growth, feed requirement and composition of carcass. Information on the performance of single-cross sows was not obtained until the fall of 1944 and is not included here.

Data and Method of Analysis

The experimental plan was for each sire to have several inbred and several single-cross litters, each of the latter to be from a dam of a different inbred line. Whenever possible, two sires were used from a line, so as to distinguish genuine differences between lines from differences between sires belonging to the same line. In 1942, there was room to obtain 19 inbred litters from only 3 lines and by 7 sires, but in 1943 11 of the lines and 21 sires were represented in the 37 inbred litters. A total of 43 different single-cross combinations were included in the 60 single-cross litters.

Viability was measured by total pigs born and number alive per litter at 21, 56 and 154 days of age. Individual weights at these four ages were used to measure rate of growth. Average daily gain and feed required for 100 pounds of gain in dry lot (on concrete) from 84 days to a final weight of about 225 pounds, as well as certain carcass measurements, were obtained on a sample of the pigs in each of the two years. Other pigs were grouped accord-

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ing to age and fed in large lots containing a little late fall pasture. The amount of alfalfa meal was adjusted to equalize the feed of dry-lot and pasture-lot pigs. Protein supplement was mixed with the grain for dry-lot pigs but was fed separately to the others. All pigs were self-fed after weaning and the kinds of feeds used were similar for the two years.

The mean differences between inbreds and crosses by the same sire were treated as the primary observations in analyzing the data in order that the

TABLE 1. SAMPLE OF INTRA-SIRE DIFFERENCES BETWEEN INBREDS AND SINGLE CROSSES IN NUMBER OF PIGS PER LITTER AT 56 DAYS

Year	Sire		Inbreds		Crosses		Mean diff. $(C-I)=D$	Weight for mean diff. $=w$[1]
	Line	No.	No. litters (n_i)	Mean pigs per litter (I)	No. litters (n_c)	Mean pigs per litter (C)		
Fall of '42	E	511	4	3.00	3	4.00	1.00	1.71
Fall of '43	B	374	1	4.00	3	5.33	1.33	0.75
Fall '42, total for 3 lines, 7 sires			19		25		1.68	9.34
Fall '43, total for 11 lines, 21 sires			37		35		1.55	16.57
Grand total for 28 sires			56		60		$1.60=\overline{D}$	$25.91=\Sigma w$

[1] $w=\dfrac{1}{\frac{1}{n_i}+\frac{1}{n_c}}=\dfrac{n_i n_c}{n_i+n_c}$

sire and line differences which affect both inbreds and crosses would not enter into the present study. Each intra-sire difference was weighted in proportion to the reciprocal of its variance, as suggested by Yates (1934). The formula for this and a sample of the data are shown in table 1.

A sample analysis of the variance in these differences is shown in table 2 for number of pigs per litter at 56 days. The mean squares between years, between lines and between sires were adjusted by multiple regression for variation among the intra-sire differences in age of dam (X), inbreeding of dam (Y) and inbreeding of litter (Z). The mean square for heterosis was adjusted to zero mean difference in X and Y but not in Z, using the partial regression with all three variables.[2] Other possible sources of error in the

[2] Adjusted mean square for heterosis

$$\frac{[\overline{D}-b_{DX.YZ}\cdot\overline{X}-b_{DY.XZ}\cdot\overline{Y}]^2}{\frac{1}{\Sigma w}+\frac{\overline{X}^2\cdot k_{X1}}{\Sigma x^2}+\frac{\overline{Y}^2\cdot k_{Y2}}{\Sigma y^2}+\frac{2\overline{XY}\cdot k_{XY}}{\sqrt{\Sigma x^2\cdot\Sigma y^2}}}$$

where k_{X1}, k_{Y2} and k_{XY} are the *multipliers* in the simultaneous equations as given by Snedecor (1940), section 13.13.

estimate obtained for heterosis are individual and line differences between the dams mated to the same boar, intra-litter variation (for pig weights), and nicking in particular combinations of lines.

The average difference between inbreds and single crosses in litter size at 56 days is significant after adjustment to zero difference in age and inbreeding of dams. The probably significant variation between lines (before adjustment) indicates that crosses exceeded inbreds more for some lines than for

TABLE 2. VARIANCE OF INTRA-SIRE DIFFERENCES BETWEEN INBREDS AND SINGLE CROSSES, IN NUMBER OF PIGS PER LITTER AT 56 DAYS

Source	Observed		Adjusted[1]	
	Degrees of freedom	Mean square	Degrees of freedom	Mean square
Mean heterosis	1	66.0**	1	33.5*
Years	1	2.8	1	23.4*
Lines of sire within years	12	12.2*	12	5.6
Sires within lines and years	14	3.9	11	3.2
Total	28	—	25	—
All sires	27	7.4	24	5.3

* for $P \leq .05$; ** for $P \leq .01$ (in this and following tables).

[1] For multiple regression on age and inbreeding of dam and on inbreeding of litters, except heterosis not adjusted for mean difference in inbreeding of litters.

others, but the smaller and insignificant variation between lines after adjustment suggests that much of this was merely the result of some lines being more highly inbred than others at the time the crosses were made. The probably significant difference between years in adjusted heterosis may be due largely to line differences in heterosis since only 3 of the more highly inbred lines were included the first year.

Results

Litter Size and Pig Weight at Four Ages

The weighted means for inbreds and crosses and the difference between them are shown in table 3. Since the dams of crosses happened to average one month younger and six percent less inbred than dams of inbreds, the differences were adjusted to remove the effect of that. These adjusted differences are given in table 3.

In litter size, crosses exceeded inbreds significantly at all four ages but the difference became larger with age because death losses were heavier among the inbreds—more than one-half among inbreds but one-third or less

among crosses. Prenatal mortality must also have been heavier among the inbreds, since there is no reason to think that the two groups of inbred sows would differ in the numbers of potentially fertile ova. Average weights per pig were practically the same for inbreds and crosses at birth and 21 days, but after that the crosses grew faster and were clearly heavier at 56 and particularly at 154 days of age. Since total weight of the litter is a combination of weight per pig and number of pigs living, both of which exhibit heterosis, total weight of litter shows more pronounced heterosis than either of its components.

TABLE 3. INTRA-SIRE COMPARISONS OF INBREDS AND SINGLE CROSSES, IN LITTER SIZE AND PIG WEIGHT AT FOUR AGES

Observation	Weighted means				Decline per 10% inbreeding of litter
	Inbreds (*I*)	Crosses (*C*)	Increase (*C*−*I*)	Adjusted increase[1]	
Inbreeding—percent:					
Of litters	42.2	5.8	−36.4	−36.4	
Of dams	33.9	28.2	− 5.7	0.0	
Age of dams—mo.	17.7	16.7	− 1.0	0.0	
Litter size—pigs:					
At birth	6.6	7.2	.6	.9*	.26
At 21 days	3.8	5.3	1.5**	1.3*	.35
At 56 days	3.5	5.1	1.6**	1.3*	.37
At 154 days	3.0	4.8	1.8**	1.4*	.39
Pig weight—lbs.:					
At birth	2.85	2.84	− .00	.08	.02
At 21 days	11.0	11.7	.7	.2	.07
At 56 days	28.1	31.7	3.6**	3.4*	.9
At 154 days	119.0	144.0	25.**	25.**	6.8
Litter weight—lbs.:					
At birth	18.8	20.4	1.7	3.1	.9
At 21 days	41.0	61.0	20.0	16.0	4.0
At 56 days	100.0	163.0	63.0	55.0	15.0
At 154 days	366.0	694.0	329.0	290.0	79.0

[1] Increase adjusted to zero mean difference for age of dams and for inbreeding of dams.

The last column in table 3 shows the average decline in performance for each 10 percent of inbreeding of the litters. These figures can be compared with estimates of the intra-year regressions of performance on inbreeding obtained by other workers. For example, the decline of 7.6 pounds in weight at 180 days found in Poland Chinas by Whatley (1942) agrees rather well with the present decline of 6.8 pounds in weight at 154 days, which is

equivalent to 8.8 pounds in terms of weight at 180 days. Also, the decline of .28 pig which Comstock and Winters (1944) found in litter size at birth per 10 percent of inbreeding of the litters is almost identical with the .26 pig decline found here. The effect of inbreeding on performance is demonstrated graphically in figure 1, where each trait in the inbreds is shown as a percentage of the mean for single crosses. On theoretical grounds one would expect the average performance of all single crosses among an unselected group of inbred lines to be that of the non-inbred foundation stock, plus the accumulated effects of selection within the lines, and less the effect of the

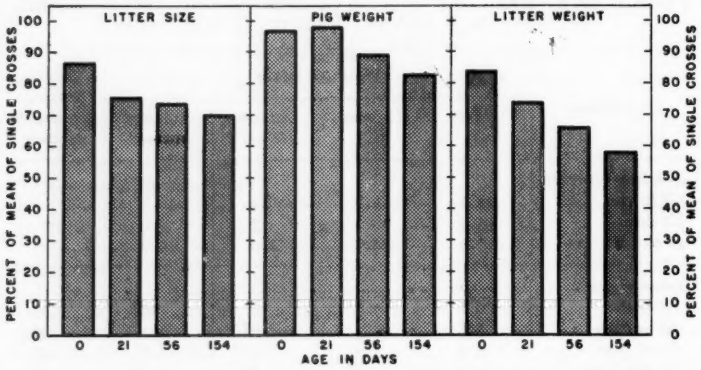

Figure 1. Performance of inbreds as percentage of the mean of single crosses after adjusting inbreds to same mean age of dam (16.7 mos.) and inbreeding of dams (28.2%) as crosses, but with inbreeding of litters 42.2% for inbreds and 5.8% for crosses.

inbreeding of the dams. In these data, the dams averaged 28 percent inbred but, even so, the performance of the single crosses averaged about the same as outbred Poland Chinas, as reported for litter size by Lush and Molln (1942; approximately 7.4 pigs at birth and 5.3 at 56 days) and for rate of growth by Winters *et al.* (1944; 1.41 pounds of gain per day from 60 days to market weight, the equivalent of about 150 pounds weight at 154 days). Because the dams would not be inbred, performance of top-crosses of the present inbred lines on outbred sows or the performance of triple crosses among these lines using single-cross dams might be expected to exceed that of outbreds considerably, particularly if only the better lines were employed.

The effect of inbreeding appears earlier and is proportionately larger on litter size or viability than on the growth rate of individual pigs. This agrees with the experiments in crossbreeding which have generally shown the percentage increase in viability to be larger than the increase in growth rate

(Lush *et al.*, 1939). However, viability and growth rate are related, in that the pigs which die are undoubtedly some of the slower growing ones. For example, the inbred pigs which lived to 154 days were a more selected sample of those born (one-half or less) than was the case for the linecross pigs (two-thirds or more). Thus if mortality had been equal among inbreds and crosses, the difference in growth rate would have favored the crosses even more than is shown by the data on the pigs which did live.

Growth Rate and Feed Requirement after 84 Days of Age

Only one lot of inbreds and one of crosses (4 pigs per lot) for each line of sire were usually fed out in dry-lot. The numbers of sire lines represented in the feeding tests were 2 (of the 3) in 1942 and 9 (of the 11) in 1943. To minimize variation from differences among the dams, a lot of inbreds included pigs from 2 or more dams and a linecross lot included pigs from dams of 2 different lines, whenever possible. About one-sixth of the inbreds (36/210) and of the crosses (54/352) which were alive at 154 days were included in these feeding trials. The inbreds and crosses for a given line of sire were usually, but not always, sired by the same boar. As before, the mean difference between inbreds and crosses, this time for each line of sire, was the unit of observation used in analyzing the data.

TABLE 4. COMPARISON OF INBREDS AND SINGLE CROSSES IN GAINS AND FEED REQUIREMENTS AFTER WEANING,[1] WITHIN LINE OF SIRE

Observation	Weighted means			
	Inbreds (*I*)	Crosses (*C*)	Difference (*C*−*I*)	
			Observed	Adjusted[2]
Number of pigs	36	54		
Inbreeding:				
Of litters (percent)	38.2	4.8	−33.4	−33.4
Of dams (percent)	28.5	30.1	1.6	1.6
Age of dams (mos.)	17.4	17.0	− 0.4	− 0.4
Initial weight (lbs.)	52.6	59.0	6.3*	0.0
Total gain (lbs.)	167.5	167.8	0.3	0.0
Daily gain (lbs.)	1.35	1.49	.14**	.03
Feed/Gain×100 (lbs.)	474	465	− 9	0.7

[1] From 84 days of age to a final weight of about 225 pounds.
[2] To zero difference in initial weight and total gain.

The results for rate of gain and feed requirement after weaning are given in table 4. The inbreds and crosses differed little in the age and inbreeding of dam (−.4 month and 1.6 percent). Linecrosses exceeded inbreds by 6.3 pounds ($P<.05$) in weight at 84 days and by .14 of a pound ($P<.01$) in average daily gain from 84 days to a final weight of about 225 pounds. The difference in feed requirement per unit of gain was trivial, indicating that the

TABLE 5. COMPARISON OF INBREDS AND SINGLE CROSSES IN CARCASS YIELDS AND DIMENSIONS, WITHIN LINE OF SIRE

Observation	Weighted means		
	Inbreds (*I*)	Crosses (*C*)	Difference (*C*−*I*)
			observed
Number of pigs	30	42	—
Inbreeding:			
Of litters—percent	40.9	4.8	−36.1
Of dams—percent	29.8	30.6	.8
Age of dams—mos.	17.1	16.9	− .2
Live weight at slaughter—lbs.	215.7	222.3	6.6±1.4
Chilled carcass yield, as percent of live slaughter wt.:			*adjusted*[1]
Total	80.0	80.6	−1.0± .8
Lean cuts: Trimmed ham	16.3	16.4	− .1± .3
Lean cuts: Trimmed loin	10.7	10.6	− .1± .3
Lean cuts: Picnic shoulder	7.9	8.0	.1± .2
Fat cuts: Trimmed belly	9.5	9.6	− .1± .3
Fat cuts: Backfat	6.8	6.5	− .9± .6
Fat cuts: Leaf fat	2.28	2.16	− .1± .2
Ratio: $\frac{\text{Fat}}{\text{Lean}}\times 100$	53.4	52.4	−3.2±2.6
Dimensions (inches):			
Length (aitch bone to 1st rib)	29.8	30.3	.1± .3
Leg length (aitch bone to hoof)	23.2	23.5	.2± .3
Depth at 7th rib	15.1	15.2	− .1± .1
Ham index $\frac{\text{circum.}}{\text{length}}\times 100$	140.6	144.0	4.0±5.5
Ham circum. (midway betw. hock and aitch bone)	20.5	21.1	.6± .6
Backfat thickness (sum of 4 places: 1st, 7th and last rib and last lumbar vertebra)	5.9	6.0	− .2± .3
Belly thickness, flank end	0.80	0.81	−.05±.04
Area of loin muscle cross section (width ×depth)	6.2	6.2	− .1± .3

[1] To zero difference in weight at slaughter (9 degrees of freedom for standard errors).

crosses consumed more feed per day but used it with about the same efficiency as the inbreds. The absolute requirements are certainly lower than the figures indicate, since a considerable but unmeasured amount of feed was spilled by the pigs into the bedding. The differences in daily gain and in feed requirement largely disappear when these are adjusted to zero difference in initial weight and total gain. This indicates that such differences in rate and economy of gain as there were between inbreds and crosses could have been predicted rather well from the difference of 6.3 pounds in weight at 84 days.

Carcass Data

Of the 4 pigs in each lot, only the first 3 to reach the 225 pound weight were usually slaughtered. The data concerning them are shown in table 5. The mean live weight at slaughter was 6.6 pounds heavier for crosses than for inbreds, but the mean differences in age and in inbreeding of the dams were negligible. After adjusting to zero mean difference in live weight at slaughter, there were no significant differences between inbreds and crosses in the carcass yields or dimensions. However, the differences would need to have been rather large for significance because of the limited data. For example, a difference of 2.0 in dressing percentage would have been necessary for the .05 level of significance. The data on carcasses do suggest, however, that the crosses tended to have a lower dressing percentage and less fat, especially backfat, but that they had slightly plumper hams than the inbreds.

Summary

To measure the effect of the inbreeding of the pigs on their performance, single crosses between inbred lines of Poland Chinas were compared with inbreds by the same boar. The 28 intra-sire comparisons included 56 inbred litters from 11 lines and 60 single-cross litters representing 43 different combinations. These were fall litters from 1942 and 1943. Inbreeding of litters averaged 42 percent for inbreds and 6 percent for single crosses; corresponding averages for inbreeding of dams were 34 and 28 percent and for age of dams were 18 and 17 months. Performance of both groups was adjusted to the same age and inbreeding of dams.

Hybrid vigor of the pigs or its converse, the effect of inbreeding, was greater in viability than in rate of growth, although the two are related in that the faster growing pigs are more likely to survive. Mortality was lower among crosses than among inbreds, both before and after birth, until at five months of age crosses exceeded inbreds by 1.4 live pigs per litter, or by 42 percent. Crosses were little heavier than inbreds at birth and 21 days, while both groups were suckling inbred sows, but crosses exceeded inbreds

by 3.4 pounds or 12 percent at 56 days and by 25 pounds or 21 percent at 154 days. In total litter weight at 154 days, crosses exceeded inbreds by 290 pounds or 72 percent. Although they grew more rapidly, crosses required as much feed as inbreds for 100 pounds of gain from 84 days to 225 pounds. Slaughter data suggested, but did not establish, that crosses had a lower dressing percentage, less fat, but plumper hams than inbreds.

These results indicate that in the development of inbred lines more careful selection is necessary to maintain litter size and viability than to hold rate of growth. The performance of these single crosses, out of dams inbred 28 percent, averaged about the same as published data on outbred Poland Chinas in Experiment Station herds. This fact suggests that the selection practiced in the development of these lines has effected considerable improvement, and that using the best of such improved lines in topcrossing on outbred sows or in triple crosses offers opportunity for surpassing the performance of outbreds.

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INDUCTION OF ESTRUS IN LACTATING SOWS WITH EQUINE GONADOTROPIN

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IN CERTAIN SPECIES, including swine, estrus is inhibited during lactation. The cause of this inhibition has received but scant attention. McKeown and Zuckerman (1938) found that destruction of the corpora lutea in lactating rats by electro-cautery did not induce estrus. They concluded that the suppression of estrus during lactation is not due solely to the corpora lutea and that lactogenic hormone may be involved. Dresel (1935) and Lahr and Riddle (1936) have shown that the estrous cycle in the rat may be inhibited with lactogenic hormone.

No careful observations appear to have been made on the completeness of estrous inhibition in the sow during lactation. Without submitting supporting data Smith (1937) states, "A sow comes in heat a few days after farrowing, usually the third, and sometimes again before the pigs are weaned." Robeson (1918) has shown that lactating sows may be brought into heat by the simple expedient of separating the young from their mothers for four or five nights, allowing the pigs to suckle only during the day. Although he gives no information on the point, it is likely that lactation is depressed by this procedure.

In this paper, the practicability of using equine gonadotropin (pregnant mare serum) to induce estrus in lactating sows is considered.

Experimental

Duroc Jersey, Poland China and Berkshire sows were injected at various stages of lactation ranging from immediately postpartum to the 68th day after farrowing. The day of farrowing was considered to be the first day of lactation. Following treatment, the sows were tested daily with a boar. The sows were left with a boar sufficiently long to determine estrus; the actual time varied from ten to sixty minutes. All of the sows coming into heat were bred and information on the size of the resulting litters was available for twenty sows. The sows used varied in age from 1 to 7 years at the time of injection and in approximate weight from 250 to 625 pounds. Neither weight nor age appeared to significantly affect the result under the conditions of this experiment.

Blood serum from pregnant ponies, filtered and treated with merthiolate to prevent bacterial decomposition, and testing about 150 international

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units (I.U.) per cc. was the form of equine gonadotropin employed. The dosage in nearly all instances varied from 750 to 1050 I.U.[2]

The results of the experiment are shown in table 1. The breed may be identified by the letter preceding the sow number: B—Berkshire; PC—Poland China; and DJ—Duroc Jersey. Of seven sows injected during the first five days of lactation only one responded and this animal received 1400 I.U. This result was surprising to us because of the recurring statement that estrus often occurs spontaneously at parturition in this species.

Estrus was not regularly induced before the fortieth day of lactation. Twenty-six of twenty-seven sows injected between the 39th and 68th days of lactation manifested estrus three to seven days after the injection. Most came into heat four or five days after treatment. The one sow which failed to come into heat (PC23) showed distinct evidence of estrus and the boar was markedly attracted but she did not actually mate. Information on resulting pregnancies is available for twenty sows bred on or after the 39th day of lactation. Nineteen became pregnant to the induced estrus during lactation; in other words, it was necessary to rebreed only one of twenty.

There were seven uninjected controls. Observation for estrus in these control animals began between the forty-seventh and fifty-fourth days of lactation and was continued for sixteen days (from May 7 to May 22, inclusive). Only one of the seven came into estrus during the test period even though they were in the declining phase of lactation and the pigs were old enough to wean. This sow came into estrus on the sixty-sixth day of lactation and was nearly dry as judged by the appearance of the mammae. The controls were tested for estrus in the same manner as the injected group. A boar was allowed to run with four other control lactating sows not shown in table 1. These sows were between the twenty-second and forty-fourth days of lactation at the time the boar was turned with them. None showed evidence of mating within the next thirty days. None became pregnant during this period as they were bred later. Smith (1937) states, "The possibility of causing most nursing sows to come in heat by turning the boar in with them has been verified by its frequent practice among farmers." From our observations it appears likely that some sows will breed during the last phases of lactation irrespective of whether they are running with the boar or are hand mated. Certainly, more evidence is necessary to verify the view that the presence of the boar hastens estrus in lactating sows.

Twenty sows were followed through pregnancy (table 1). The size of litter and the length of pregnancy appear to be within normal limits. As re-

[2] Some preliminary information on dosage was obtained by injecting 1000 to 6000 I.U. into five-month old gilts. Some gilts were sacrificed to study the ovarian response while others were bred and allowed to go through pregnancy. The results indicated that 1000 I.U. produced a definite response. We gratefully acknowledge the assistance of Mr. L. W. Feldmiller with these early experiments.

TABLE 1. INDUCTION OF ESTRUS IN LACTATING SOWS WITH EQUINE GONADOTROPIN

Sow No.	Day of lactation*	I.U. equine gonadotropin	Date of injection	First day of estrus	Date of farrowing	No. pigs born	Length of pregnancy
PC 116	1	700	Mar. 27, '45	None	—	—	—
B 71	2	1400	May 20, '45	May 21, '45	Rebred	—	—
PC 60	2	700	Mar. 27, '45	None	—	—	—
PC 123	2	700	Mar. 27, '45	None	—	—	—
DJ 48	4	700	Mar. 27, '45	None	—	—	—
DJ 48	5	700	Mar. 27, '45	None	—	—	—
PC 112	5	700	Mar. 27, '45	None	—	—	—
B 28	21	1050	May 20, '44	None	—	—	—
DJ 20	30	1050	May 20, '44	None	—	—	—
DJ 48	30	1050	May 20, '44	None	—	—	—
PC 60	30	750	Nov. 26, '43	Nov. 30, '43	Mar. 29, '44	4	120
PC 13	35	750	May 6, '43	May 12, '43	No data†	—	—
B 60	37	450	May 6, '43	None	—	—	—
B 27	38	750	Nov. 26, '43	None	—	—	—
DJ 5	38	750	May 6, '43	May 11, '43	Rebred	—	—
PC 1	39	750	May 6, '43	May 11, '43	Sept. 2, '43	10	113
B 70	41	750	May 6, '43	May 10, '43	No data	—	—
DJ 48	42	1500	May 20, '43	May 25, '43	No data	—	—
PC 5	42	1050	May 20, '43	May 25, '43	No data	—	—
PC 23	42	1500	May 20, '43	May 23, '43	No data	—	—
PC 3	43	1050	May 20, '43	May 24, '43	No data	—	—
PC 22	43	1500	May 20, '43	May 25, '43	No data	—	—
PC 60	44	980	May 7, '45	May 12, '45	Sept. 8, '45	6	119
PC 112	46	980	May 7, '45	May 11, '45	Sept. 4, '45	8	116
DJ 216	47	980	May 7, '45	May 14, '45	Rebred	—	—
PC 220	50	980	May 7, '45	May 12, '45	Sept. 7, '45	6	118
PC 103	51	980	May 7, '45	May 12, '45	Sept. 6, '45	11	117
B 71	51	1050	Nov. 8, '43	Nov. 13, '43	Mar. 9, '44	11	117
PC 123	52	960	Nov. 24, '44	Nov. 28, '44	Mar. 26, '45	5	118
PC 222	52	980	May 7, '45	May 12, '45	Sept. 4, '45	3	115
PC 23	53	980	May 7, '45	None	—	—	—
PC 112	53	960	Nov. 24, '44	Nov. 28, '44	Mar. 23, '45	15	115
PC 5	53	1050	Nov. 8, '43	Nov. 13, '43	Mar. 7, '44	13	115
PC 7	55	1050	Nov. 8, '43	Nov. 13, '43	Mar. 1, '44	14	109
PC 7	55	1050	May 20, '43	May 24, '43	Sept. 15, '43	10	114
PC 60	55	960	Nov. 24, '44	Nov. 28, '44	Mar. 26, '45	10	118
PC 116	55	960	Nov. 24, '44	Nov. 28, '44	Mar. 27, '45	3	119
PC 22	56	980	May 7, '45	May 13, '45	Sept. 6, '45	7	116
DJ 48	57	750	Nov. 26, '43	Dec. 1, '43	Mar. 19, '44	9	109
DJ 48	66	960	Nov. 24, '44	Nov. 29, '44	Mar. 24, '45	12	115
DJ 48	67	960	Nov. 24, '44	Nov. 29, '44	Mar. 23, '45	12	114
PC 1	68	1050	Nov. 8, '43	Nov. 13, '43	Mar. 6, '44	6	114
DJ 218	47**	Control	—	None	—	—	—
DJ 204	47**	Control	—	None	—	—	—
DJ 206	50**	Control	—	None	—	—	—
PC 81	51**	Control	—	None	—	—	—
DJ 20	53**	Control	—	None	—	—	—
PC 1	53**	Control	—	None	—	—	—
DJ 11	54**	Control	—	May 19, '45	Rebred	—	—

* Refers to day on which injection was made.

† Sold before farrowing.

** Refers to day of lactation on which first tested for estrus. Observations began on May 7, 1945, and continued through May 22. Seven of eight other sows at comparable stages of lactation injected on May 7, came into estrus by May 14.

gards length of pregnancy, Carmichael and Rice (1920) reported that 73.8 percent of 549 farrowings recorded by them were between 113 and 117 days with extremes of 98 and 124 days. According to Hughes (unpublished) the average gestation period under our conditions for a total of 658 farrowings was 115.0 days. In the present experiment farrowing was prolonged over several days in two sows; this may or may not be related to the treatment.

Of interest is the fact that estrus was not regularly induced before the fortieth day. This may indicate that a decline in lactation occurs at this time. Possibly sows with small litters or sows producing little milk will respond earlier in lactation than those with large litters.

These experiments indicate that the time between successive farrowings can be shortened by two to four weeks by the use of equine gonadotropin on or after the fortieth day of lactation. A distinct advantage is that the farrowing season can be concentrated within a shorter period by allowing the early farrowing sows to breed normally at the end of lactation and inducing estrus in the late farrowing sows during lactation. Furthermore, it becomes possible to allow the pigs to suckle longer, if desirable, and still obtain two litters per year.

Although these results appear extremely promising, we have a forewarning of difficulties which may be encountered in the field. For example, a field trial was initiated during the summer of 1945 with pure bred Berkshires. The injections were made by the farm manager. Estrus was observed in only 6 of 18 sows injected between the 40th and 54th days of lactation. Observations of estrus were made by the herdsman, a relatively inexperienced hogman, and some estrous periods may have been missed. In only one known particular did the procedure vary from our own—the dosage was slightly reduced. It may be that the dosages employed were borderline.

Summary

Forty-two sows were injected with approximately 1000 I.U. equine gonadotropin during lactation to induce estrus. Sows which were injected in early lactation (1 to 38 days) did not manifest estrus regularly but 26 of 27 sows injected between the thirty-ninth and sixty-eighth days of lactation came into heat three to seven days following treatment. All of these animals were bred. Twenty of 23, on which information was available, became pregnant during this induced estrus. The practical aspects of the problem are briefly discussed.

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SINGLE WEIGHT VERSUS A THREE-DAY-AVERAGE WEIGHT FOR SWINE

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TAKING individual weights of swine on three consecutive days at the beginning and again at the end of a feeding experiment has long been the practice of research workers. It is believed that more than one weight is necessary in order to obtain a satisfactory measure for an experimental animal.

Few studies have been made to determine the relative accuracy of a single weight versus a three-day-average weight. Lush (1928) observed the weights of steers and found an experimental error of six to twelve pounds in one-day weights. In an earlier study Lush and Black (1926) concluded that "the increased accuracy justifies the trouble and expense of two extra weighings" of steers under experimental feed-lot conditions. They also concluded that "the one-day weight is not so inaccurate as to be useless for experimental purposes. . . . It is only necessary to allow for a larger experimental error in interpreting the results when they are based on one-day weights."

Hale and Godbey (1935) conducted an experiment in which 45 pigs were weighed for 12 consecutive hours for three consecutive days. This study did not endeavor to compare the relative accuracy of the weights of a pen of animals each weighed individually on one day with the three-day-average weight of the same group of animals.

Source of Data

The data used are actual weighings of pigs at the Illinois Agricultural Experiment Station. Made over a period of years under various conditions, they are official starting and/or final weights of 3,323 self-fed experimental animals. Both the beam and the Toledo dial scales were used, but no effort was made to segregate the results obtained with one type of scale from the other.

Results and Discussion

The deviation of the first-day weight from the three-day average is shown in table 1. Seventy-six pigs are grouped in weights between 27 and 39 pounds. Twenty-one weighed one pound less the first day than their three-day average, 51 weighed the same, and four weighed one pound more. The mean deviation of this group, influenced by the amount but not by the direction, is .33 pound. This mean deviation increases as the weight increases, rising to 1.83 pounds for pigs weighing between 200 and 219 pounds.

TABLE 1. DEVIATIONS OF FIRST-DAY WEIGHTS FROM AVERAGE WEIGHTS FOR THREE DAYS

Weight interval (pounds)	Number of pigs	Distribution of deviations of the first-day weight from three-day average (minus and plus deviations are in pounds)											Mean deviation
		−5	−4	−3	−2	−1	0	1	2	3	4	5	
27–39	76					21	51	4					.33
40–49	190			3	11	48	86	36	5	1			.67
50–59	273			2	16	82	130	38	5				.62
60–69	452	1	1	6	57	161	168	48	9	1			.82
70–79	379	1	1	20	49	125	126	46	8	3			.96
80–99	271			4	40	84	94	32	8	7	2		.93
100–139	242		3	18	51	70	61	25	8	3	2	1	1.24
140–159	226	2	6	17	41	70	55	27	7	1			1.24
160–179	327	2	16	41	75	85	59	38	9	2			1.51
180–199	320	5	26	42	65	85	68	21	4	2	2		1.60
200–219	274	5	21	44	85	51	38	21	9				1.83
220–over	293	13	20	43	63	58	53	26	14	2	1		1.78
Total and averages	3,323	29	94	240	553	940	989	362	86	22	7	1	1.18

Handling, change of diet, and other environmental factors may influence the weights on the second and third days. The normal rate of gain for a short interval of time can be expressed by a straight line with a slope equal to the average daily gain. The weights of individuals will fluctuate about a line, but the means of several groups will tend to deviate only slightly unless these outside factors exert undue influence.

In the charts in figure 1, showing a few representative weight groups it is noted that the lines connecting the mean weight for each of the three consecutive days forms a broken line graph rather than a straight line. The mean daily weights in the 150- to 159-pound group, which includes 112 pigs, fall along a straight line. Apparently the excitement incident to the first day of weighing is reflected in the second-day weight. In most cases the groups show a decided increase in weight on the third day.

Further evidence of the relative value of the two methods of weighing is obtained by studying the variation in weights obtained on three consecutive days. If each pig in a lot weighs exactly the same on all three days there will be no difference between the daily means, standard deviations and standard errors, nor will these differ from the same factors obtained from the three-day-average weights. If all weights are considered as a group and

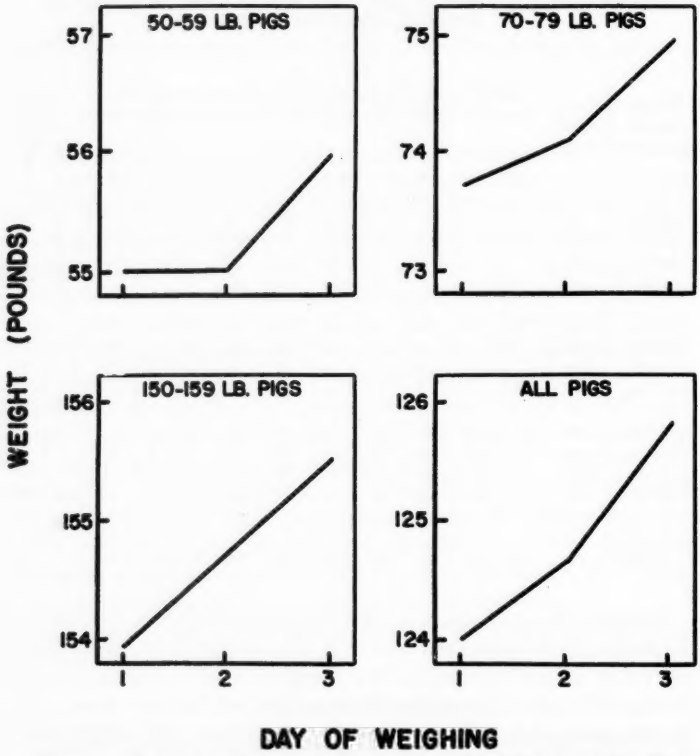

Figure 1. Comparison between first, second, and third day weights. There were 273 pigs in the weight interval 50 to 59 pounds, 379 in the 70 to 79 pound interval, and 112 in the 150 to 159 pound interval. The complete study is based on the weights of 3,323 pigs.

as so many independent individual weights, the mean and standard deviation will remain the same as for a single day, but the standard error will be divided by the square root of 3. These factors, therefore, can serve as a measure of comparison.

In order to eliminate in so far as possible any variation due to size, the weights were first sorted into groups having the same three-day average. A few representative weight groups are shown in table 2. These few groups show a tendency to vary more in second- and third-day weights than in first-day weights.

In table 3 all weights are grouped into 10-pound intervals to minimize

TABLE 2. COMPARISON OF THE MEANS OF DAILY WEIGHTS OF PIGS IN SELECTED WEIGHT GROUPS

Approximate 3-day average (pounds)	No. of pigs	1st day weights (pounds)	2nd day weights (pounds)	3rd day weights (pounds)	All weights (pounds)	Standard error of three times the first day weight
30	10	29.90±.11	29.70±.15	30.70±.21	30.10±.12	.06
40	4	39.25±.29	40.50±.29	40.50±.29	40.08±.23	.17
50	27	49.26±.20	49.81±.21	50.93±.23	50.00±.14	.12
60	42	59.74±.11	59.93±.18	60.55±.19	60.07±.10	.06
70	36	69.08±.19	70.03±.16	70.81±.19	69.97±.12	.11
80	25	79.84±.32	79.84±.18	80.00±.41	79.89±.18	.18
100	10	99.70±.26	99.90±.28	100.10±.38	99.90±.18	.15
150	14	149.07±.36	150.00±.26	150.93±.40	150.00±.23	.21
200	18	199.00±.26	199.56±.29	201.39±.36	199.98±.22	.15

TABLE 3. COMPARISON OF THE MEANS OF DAILY WEIGHT OF PIGS WITHIN TEN POUND WEIGHT INTERVALS

Weight interval (pounds)	No. of pigs	1st day weights (pounds)	2nd day weights (pounds)	3rd day weights (pounds)	Three-day average (pounds)	All weights (pounds)	Standard error of three times the first day weights
27–39	76	31.47±.40	31.66±.45	32.03±.43	31.67±.42	31.72±.25	.23
40–49	190	46.64±.16	46.58±.20	47.32±.22	46.82±.18	46.85±.11	.09
50–59	273	55.04±.16	55.04±.19	55.96±.19	55.30±.17	55.35±.11	.09
60–69	452	64.53±.14	64.83±.17	65.78±.17	65.04±.15	65.04±.09	.08
70–79	379	73.70±.15	74.13±.17	74.96±.27	74.28±.15	74.26±.12	.09
80–89	158	83.59±.21	83.75±.27	84.50±.32	83.95±.24	83.95±.16	.12
90–99	113	95.63±.26	95.74±.32	96.57±.33	95.98±.28	95.98±.17	.15
100–109	114	102.99±.23	103.94±.27	104.52±.26	103.82±.23	103.82±.15	.13
110–119	21	113.86±.68	115.10±.82	116.10±1.12	115.10±.82	115.02±.52	.39
120–129	66	125.67±.30	126.17±.36	126.12±.47	126.00±.30	125.98±.22	.17
130–139	41	133.66±.46	134.41±.54	135.37±.65	134.44±.50	134.48±.32	.27
140–149	114	145.61±.26	146.73±.27	147.13±.30	146.47±.24	147.49±.16	.15
150–159	112	153.84±.29	154.63±.32	155.42±.41	154.68±.31	154.63±.20	.17
160–169	130	164.04±.28	165.19±.33	166.14±.41	165.09±.32	165.12±.20	.16
170–179	197	174.83±.20	175.72±.26	177.52±.29	176.02±.24	176.02±.15	.12
180–189	181	184.28±.22	185.43±.29	187.34±.35	185.67±.27	185.68±.18	.13
190–199	139	194.19±.23	195.04±.31	197.07±.33	195.46±.26	195.43±.18	.13
200–209	144	204.37±.24	205.57±.30	207.78±.34	205.93±.26	205.91±.18	.14
210–219	130	214.38±.26	215.89±.33	217.59±.32	215.93±.28	215.96±.19	.15
220–229	102	224.01±.26	225.47±.37	227.26±.39	225.60±.30	225.58±.21	.15
230–239	84	233.42±.30	233.71±.45	236.27±.49	234.44±.37	234.47±.25	.17
240–249	53	243.34±.38	244.89±.47	246.68±.50	244.93±.39	244.97±.28	.22
over 250	54	263.81±1.63	264.50±1.70	266.74±1.72	265.07±1.66	265.02±.97	.94
Total and averages	3,323	124.02±1.13	124.65±1.14	125.82±1.15	124.83±1.14	124.83±.66	.65

variation due to size of pigs. The grouping was made according to first-day weights. A few calculations were also made from groupings according to the third-day weight and a few from groupings in which all weights were within the 10-pound interval. The results of these calculations were consistent with the findings recorded in table 3.

The mean of the first-day weighings of the 27- to 38-pound group, in which there were 76 pigs, is 31.47 pounds, with a standard error of .40 pound. The mean of the second day is $31.66 \pm .45$; the third day, $32.03 \pm .43$; and the three-day averages, $31.67 \pm .42$. These differences cannot be called significant, but they do tend to show that there is more variation in the three-day-average weights than in the first-day weights. There is also more variation in the second- and third-day weights than in the first-day weights. The average of the 218 individual weighings was $31.72 \pm .25$. Assuming that all pigs weighed the same on three consecutive days, the average would have been $31.47 \pm .23$.

If there is no difference in the reliability of the weighings, we can expect the standard errors of each group to be approximately equal. We can further expect them to vary around each other. In a comparison of first-day weights with the three-day average, chance variation should produce a smaller standard error in each group an equal number of times.

In the 23 weight intervals the standard error of the first-day weights is less than the standard error of the three-day average in 19 cases, the two standard errors are equal in three cases, and the standard error of the three-day average is less than the standard error of the first day in one case. The expectancy of obtaining a similar distribution due solely to chance is slight enough to warrant calling these results very highly significant.

The fact is emphasized that the difference between the standard error of the first-day weight and the standard error of the three-day average is in no single case significant. These results warrant further consideration because of the fact that the results appear to be cumulative.

Summary

The deviation between the first-day weight and the three-day average increases as the size of the pig increases because the heavier pig usually has a higher average daily gain than the smaller pig.

Apparently the excitement created in handling the animal on the first day has considerable influence on the second-day weight, and this condition is reflected in the three-day average.

There is usually less variation in first-day weights than in the second or third or in the average of the three weights. Such being the case, errors are

actually introduced into the results instead of ruling them out by using a three-day average.

Finally, statistical analysis of these data has failed to show any advantage in continuing the practice of obtaining a three-day-average weight rather than a single weight at the beginning and again at the end of a feeding experiment. The author recommends careful weighing on one day so as to avoid frequent errors in weighing and in reading scales, and the discontinuance of the practice of taking weights on more than one day.

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WAXY CORN VERSUS NON-WAXY CORN FOR GROWING FATTENING PIGS FED IN DRY LOT[1]

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IN 1908 Reverend J. M. W. Farnham of the American Presbyterian Mission at Shanghai, China, sent a small sample of shelled Chinese corn to the Office of Foreign Seed and Plant Introduction (Collins, 1909). Collins planted this corn and studied its characteristics. He noted that the endosperm of this Chinese variety had a distinctly different appearance and texture than the common dent varieties grown in the United States. Because the texture and physical appearance resembled that of a hard wax, he suggested the term cereous or waxy endosperm.

Apparently there was little active industrial interest in waxy corn prior to the outbreak of war in the Pacific. According to Schopmeyer, *et al.* (1943) from 93 to 97 percent of the tapioca (cassava) starch used by industry was imported from the Netherlands Indies. With this source of supply eliminated, an active interest developed in the possible use of starch from waxy corn and other waxy cereals as a substitute for that portion of the tapioca starch which was used for certain purposes because of its peculiar properties. The results of laboratory tests made by industrial laboratories which use large quantities of tapioca starch in the manufacture of adhesives, gums, paper sizes, and puddings have been reported by Hixon and Sprague (1942). These results indicated that after minor adjustments in the processing method were made, products could be obtained from waxy cornstarch which were very similar to those from tapioca starch. These results were confirmed by Schopmeyer, *et al.* (1943).

With the increased industrial interest in waxy corn, the question arose as to the feeding value of this cereal. This question might become important if a surplus were produced and it should become necessary to dispose of the surplus by feeding it to livestock. No answers to this question have been found in the literature. Thus, it was considered desirable to make a study of the feeding value of waxy corn for pigs. A variety of waxy corn known as Nebraska Waxy was used. It was developed at the Nebraska Agricultural Experiment Station from seed obtained from Collins and from seed of two standard non-waxy[3] varieties. The character and field performance of this variety have been reported by Kiesselbach (1944).

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[2] Acknowledgement is made to Dr. T. A. Kiesselbach, agronomist in the Nebraska Agricultural Experiment Station for suggesting the project, and for making available the waxy corn needed in these trials. Credit is due Winfred Reimer and Leslie Kaufman who fed and cared for the pigs in 1943 and 1944 respectively.

[3] Throughout this paper the term "non-waxy" corn is used to designate the common type of dent corn.

Experimental Procedure

In each of two feeding trials, 30 pigs were self-fed in three lots as follows:

Lot 1—Shelled, non-waxy corn and protein supplement, free choice.

Lot 2—Shelled, waxy corn and protein supplement, free choice.

Lot 3—Shelled, non-waxy corn, shelled, waxy corn and protein supplement free choice. The protein supplement used was composed of equal parts by weight of tankage, soybean oil meal and alfalfa meal.

In a third trial, 28 pigs were self-fed in two lots as follows:

Lot 4—A mixture of ground, non-waxy corn, tankage, soybean oil meal and alfalfa meal.

Lot 5—A mixture of ground, waxy corn, tankage, soybean oil meal and alfalfa meal.

Both of these mixtures were fed at the same level of crude protein. The first two weeks the pigs were fed mixtures which contained approximately 22 percent protein. From that point (average weight of pigs 71 pounds) to a weight of about 125 pounds, the mixtures contained approximately 18 percent protein, and for the remainder of the trial, approximately 13 percent protein. All mixtures contained 7 percent alfalfa meal. Tankage and soybean oil meal were included in equal proportions and the desired percent of crude protein in the mixtures was obtained by varying the amount of these supplements and the amount of corn.

A simple mineral mixture composed of 2 parts ground limestone, 2 parts steamed bone meal and 1 part salt (by weight) was self-fed to each lot of pigs in each of the trials.

The yellow, non-waxy corn fed was purchased on the open market and was of good quality. The waxy corn fed was Nebraska Waxy, a yellow variety. It was grown on the Experiment Station farm. The corn fed to lots 4 and 5 was ground moderately fine.

The composition of the non-waxy and waxy corn, respectively, fed in 1943, was as follows (moisture-free basis): protein 11.0 and 14.0; ether extract 3.5 and 4.2; fiber 2.0 and 2.2; ash 1.7 and 1.9; nitrogen-free extract 81.8 and 77.7. The composition of the non-waxy and waxy corn, respectively, fed in 1944, was as follows (moisture-free basis): protein 10.8 and 11.4; ether extract 4.6 and 4.9; fiber 2.2 and 2.7; ash 1.6 and 1.9; nitrogen-free extract 80.8 and 79.1.

The digester tankage and expeller process soybean oil meal used were standard products. The alfalfa meal fed in the first trial was made from field-cured, fourth-cutting hay grown in 1942. The alfalfa meal fed in the first part of the 1944 trials was made from field-cured, second-cutting hay grown

in 1943, and was of only fair quality. The alfalfa meal fed during the remainder of the 1944 trials was artificially dehydrated, second-cutting alfalfa and was produced in 1944. It was excellent in quality.

The pigs used in 1943 were farrowed on rye pasture in February. Unfavorable weather prevailed throughout the suckling period. They were weaned at eight weeks and placed in concrete-floored pens at ten weeks. The test was started when the pigs had reached an average age of thirteen weeks.

The pigs used in 1944 in lots 1, 2 and 3 were farrowed in March on pasture containing rye and alfalfa. Because of the unfavorable weather, little use was made of the pasture prior to weaning. The pigs were weaned at eight weeks and placed on test at an average age of ten weeks. The pigs used in lots 4 and 5 were farrowed in May on sweet clover pasture. They were weaned at eight weeks and placed on test at an average age of eleven weeks. All of the pigs were creep-fed during the suckling period, the boar pigs were castrated at approximately four weeks of age, and all pigs were vaccinated for cholera (simultaneous method) from three to five weeks prior to the start of the tests.

The pigs were allotted as uniformly as possible, on the following considerations: breed, sex and weight. They were weighed at 14-day intervals throughout the tests, except at the conclusion of each test. It was planned to feed each lot to an average weight per pig of 200 pounds. This was done only in the second trial. In the first and third trials the respective lots were fed for the same number of days. They were housed in open sheds paved with concrete and each lot also was provided with a concrete-paved, open pen for exercise. Each lot was provided with an automatic watering device and with similar self-feeders. For lot 3 an additional feeder was used to provide room for the two kinds of corn fed.

Results and Discussion

The essential data are presented in tables 1 and 2. In the first trial (table 1) the pigs fed waxy corn (lot 2) made slightly more rapid and efficient gains than either of the other two lots. In the second trial the pigs fed both kinds of corn (lot 3) made the most rapid gains and the pigs fed the waxy corn (lot 2) made the least efficient gains. The mean results show that there is no appreciable difference between the three groups either in rate of gain or efficiency of gain. The pigs fed both kinds of corn (lot 3) consumed more corn daily than either of the other lots, in both trials. The reason for this is not apparent. The pigs in lot 3 were provided with more feeder space, but it is difficult to believe that this was a factor because all lots had more than ample space. The pigs fed the waxy corn (lot 2) consumed more corn

TABLE 1. WAXY CORN VS. NON-WAXY CORN, SELF-FED WITH SUPPLEMENTS FREE CHOICE, TO PIGS IN DRY LOT

Items compared	First trial 1943 summer			Second trial 1944 summer			Summary 2 trials, 1943–44		
	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
	Non-waxy corn	Waxy corn	Non-waxy & waxy	Non-waxy corn	Waxy corn	Non-waxy & waxy	Non-waxy corn	Waxy corn	Non-waxy & waxy
No. of pigs started	10	10	10	10	10	10	20	20	20
No. of pigs finished	10	10	9[1]	8[2]	9[3]	9[4]	18	19	18
No. of days fed	113	113	113	137	137	128	125	125	120.5
Av. initial weight, lbs.	58.7	58.3	58.4	42.8	42.4	43.0	50.8	50.4	50.7
Av. final weight, lbs.	191.0	194.9	189.6	200.3	201.5	201.1	195.1	198.0	195.4
Av. daily gain, lbs.	1.17	1.21	1.16	1.11	1.13	1.20	1.14	1.17	1.18
Av. daily feed, lbs.									
Non-waxy corn, shelled	3.68	—	3.04	3.28	—	2.43	3.48	—	2.72
Waxy corn, shelled	—	3.82	.92	—	3.47	1.15	—	3.63	1.04
Protein supplement	.81	.76	.81	.75	.79	.77	.78	.77	.79
Total	4.49	4.58	4.77	4.03	4.26	4.35	4.26	4.40	4.55
Feed required per 100 lbs. gain, lbs.									
Non-waxy corn, shelled	314.62	—	260.9	296.7	—	202.3	305.7	—	229.8
Waxy corn, shelled	—	315.6	79.2	—	306.5	96.0	—	311.0	88.1
Protein supplement	69.3	63.0	69.7	67.5	69.4	63.9	68.4	66.3	66.6
Total	383.9	378.6	409.8	364.2	375.9	362.2	374.1	377.3	384.5
Calculated average protein content of self-balanced rations (percent)	15.5	16.9	14.7	14.9	15.3	14.6	15.2	16.1	14.7

[1] One pig died 56 days after the start of the test, with no previous symptoms of illness. Cause of death unknown.
[2] One pig was removed after 28 days due to a severe umbilical hernia. One pig was removed after 56 days due to a respiratory disturbance. It died 2 days later.
[3] One pig was removed after 28 days due to acute illness. Post-mortem inspection revealed an acute pneumonia.
[4] One pig was removed after 28 days because it was making little growth and had a very unthrifty appearance.

daily than the pigs fed non-waxy corn (lot 1) in both trials. This seems somewhat paradoxical when we note that the pigs obviously prefer non-waxy corn to waxy corn when they have a choice (lot 3).

The corn fed to the pigs in lot 3 was weighed back at regular intervals and the location of the two kinds of corn was changed each time. However, the pigs preferred the non-waxy to the waxy corn at all stages of development from 43 pounds to approximately 200 pounds live weight. The ratio of preference was 3.3:1 and 2.1:1 in the 1943 and 1944 trials, respectively. The average ratio of preference for both trials was 2.6:1. The data on mineral consumption is omitted from the tables because the pigs wasted more mineral than they consumed.

TABLE 2. WAXY CORN VS. NON-WAXY CORN, SELF-FED IN MIXED RATIONS, OF THE SAME PROTEIN CONTENT, TO PIGS IN DRY LOT

Items compared	From 56–125 lbs.		From 125–200 lbs.		From 56–200 lbs.	
	Lot 4 non-waxy corn	Lot 5 waxy corn	Lot 4 non-waxy corn	Lot 5 waxy corn	Lot 4 non-waxy corn	Lot 5 waxy corn
No. of pigs started	14	14	12**	13**	14	14
No. of pigs finished	13*	14	12	13	12	13
No. of days fed	56	56	47	47	103	103
Av. initial weight, lbs.	56.4	56.4	128.1	127.5	56.4	56.4
Av. final weight, lbs.	124.0	124.8	200.6	193.3	200.6	193.3
Av. daily grain, lbs.	1.21	1.22	1.54	1.40	1.35	1.30
Av. daily feed, lbs.						
Non-waxy corn, ground	3.44	—	6.21	—	4.61	—
Waxy corn, ground	—	3.31	—	5.66	—	4.34
Tankage	.51	.46	.28	.22	.41	.36
Soybean oil meal	.51	.46	.28	.22	.41	.36
Alfalfa meal	.34	.32	.51	.46	.41	.38
Mineral	.02	.02	.02	.02	.02	.02
Total, lbs.	4.82	4.57	7.30	6.58	5.86	5.46
Feed required per 100 lbs. gain, lbs.						
Non-waxy corn, ground	283.1	—	402.6	—	340.7	—
Waxy corn, ground	—	271.1	—	404.7	—	334.1
Tankage	42.0	37.9	18.4	16.0	30.6	27.5
Soybean oil meal	42.0	37.9	18.4	16.0	30.6	27.5
Alfalfa meal	27.6	26.1	33.1	32.9	30.2	29.3
Mineral	1.5	1.5	1.1	1.2	1.3	1.3
Total, lbs.	396.2	374.5	473.6	470.8	433.4	419.7
Calculated protein content of mixtures fed (percent)						
First two weeks	22.2	22.1	—	—	—	—
Remainder of, or total period	17.8	17.8	13.1	13.1	15.7	15.7

* One pig died after 49 days, with no previous symptoms of illness. Cause unknown.

** One pig was removed from each lot when the rations were changed for the second part of the feeding period, due to an unthrifty condition of these individuals.

In the trial in which mixed rations were fed (table 2) the pigs fed the non-waxy corn mixtures (lot 4) consumed more feed daily during both "growth" periods (56–125 pounds and 125–200 pounds) than the pigs fed the waxy corn mixtures (lot 5). This may be due to the fact that the non-waxy corn mixtures contained somewhat more protein supplement. Between the weights of 56 and 125 pounds, both lots of pigs made the same

daily rate of gain. Between the weights of 125 and 200 pounds, the pigs fed the non-waxy corn mixture made appreciably faster gains than the pigs fed the waxy corn mixture. If we consider the entire feeding period, the difference between the two lots in average daily gain is not significant. The most efficient gains in both periods were made by the pigs which were fed the waxy corn mixture. Considering the limited amount of data, this difference is too small to be significant. If we consider the data from the three trials and both methods of feeding it is apparent that there is no appreciable difference between the feeding value of waxy corn and non-waxy corn when they are self-fed with a protein and mineral supplement to pigs in dry lot. This is in agreement with results obtained with chicks by Mussehl (1944).

It is interesting to note that the pigs which balanced their own rations consumed less protein than the pigs which were fed mixed rations.

Summary

Eighty-eight pigs were self-fed in three trials to compare the feeding value of waxy corn with that of non-waxy corn, when each is fed with a good protein supplement and mineral supplement in dry lot. When given a choice of both kinds of corn, the pigs consumed 2.6 times as much of the non-waxy corn as they consumed of the waxy corn. However, the overall response of the pigs fed only waxy corn was fully equal to that of the pigs fed the non-waxy corn.

The waxy corn used contained slightly more protein, fiber, ether extract, and ash, and less nitrogen-free extract than the non-waxy corn.

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ADDITION OF SYNTHETIC NUTRIENTS TO PROTEIN SUPPLEMENTAL FEEDS IN SWINE RATIONS[1]

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THE HIGH EFFICIENCY of fish meal and tankage as sources of supplementary protein to corn in rations for growing pigs has been demonstrated at several experiment stations (Kyser and Jones, 1939; Robison, 1942). That animal and fish proteins often supplement grains more effectively than soybean oilmeal protein is also shown by experimental data (Ellis and Zeller, 1943; Fairbanks, *et al.*, 1944; Ferrin, 1943). Fish meal appears to contain some essential dietary factors which are water soluble. The factors choline and methionine are present in fish meal in comparatively large amounts and have proved of considerable consequence in the supplementation of soybean oilmeal for chicks. They also may be of some importance in the nutrition of pigs. During the war period, soybean oilmeal has become one of the largest sources of protein in swine rations. The possibility of improving soybean oilmeal protein by the additions of choline and methionine led to the feeding of five lots of pigs during the summer of 1944.

Experimental

A solvent processed, toasted, soybean oilmeal was fed in comparison with dry rendered tankage and sardine type fish meal to growing pigs. Soybean oilmeal also was supplemented with choline chloride, lot 4, and with *dl*-methionine,[3] lot 5. The rations were proportioned to supply equal amounts of supplemental protein with the total protein ranging from 17.0 to 17.8 percent. Ground yellow corn was the base for all rations plus dried whey, dehydrated alfalfa leaf meal, irradiated yeast, iodized salt, riboflavin and niacin. Defluorinated rock phosphate was included in the rations except the one in which tankage furnished the supplementary protein. The composition of the rations for each of the five lots is given in table 1.

Thrifty pigs of approximately 50 pounds initial weight were self-fed for a period of 103 days, June 30 to October 11, 1944. One pig in lot 3 died following an operation for piles after 42 days on feed and another pig from lot 3 which failed to make an average of one pound daily gain was removed after 70 days of feeding. The feed consumption for lot 3 was adjusted by

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deducting from the total consumed in 103 days the average amount eaten by one pig of the lot. The pigs were housed in pens in a concrete floored barn and had access to sunshine in lots paved with concrete.

The corn fed in this experiment was grade 2, yellow corn ground through a .50 inch screen in a hammer mill. The tankage was a dry rendered product

TABLE 1. RATIONS FED

Feeds	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
Ground yellow corn	78.0	78.7	70.5	70.4	70.4
Dried whey	2.5	2.5	2.5	2.5	2.5
Dehydrated alfalfa leaf meal	5.0	5.0	5.0	5.0	5.0
Irradiated yeast (9000 U.S.P. Units D/gm.)	.02	.02	.02	.02	.02
Iodized salt	0.5	0.5	0.5	0.5	0.5
Defluorinated phosphate	—	1.1	1.9	1.9	1.9
Tankage	14.0	—	—	—	—
Sardine meal	—	12.2	—	—	—
Soybean oilmeal	—	—	19.6	19.6	19.6
Choline chloride	—	—	—	0.1	—
dl-methionine	—	—	—	—	0.1
Riboflavin	300 micrograms per 100 grams for each ration				
Niacin	3 milligrams per 100 grams for each ration				

guaranteed 60 percent protein, manufactured by the Cudahy Packing Co., Newport, Minnesota. Sardine type, fish meal manufactured by R. J. Roesling & Co., San Francisco, California, was guaranteed at 70 percent protein content. Solvent process, toasted soybean oilmeal, 44 percent protein, was manufactured by Archer-Daniels-Midland, Chicago, Illinois. The choline chloride was furnished by Lederle Laboratories, Pearl River, New York. Upon analysis, the tankage contained 63 percent protein; the fish meal, 72.5 percent protein and the soybean oilmeal, 45 percent protein.

The ingredients of the rations were so proportioned that they furnished

TABLE 2. PROXIMATE ANALYSES OF MIXED RATIONS

Ration	Protein	Crude fat	Crude fiber	Ash	Nitrogen free extract	Moisture
1	17.6	2.9	3.7	4.0	73.6	13.9
2	17.3	3.7	3.8	3.7	71.3	14.0
3	17.7	2.9	3.6	5.4	70.0	12.6
4	17.8	3.2	3.8	5.4	69.5	12.6
5	17.0	3.2	4.1	4.9	70.5	12.6

approximately equal amounts of each nutrient. The same level of protein was fed throughout the entire feeding period.

Analyses of the mixed rations were furnished through the courtesy of the Division of Agricultural Biochemistry. Percentages are reported on the dry matter basis, in table 2.

Results and Discussion

The data covering weights and gains are summarized in table 3. The pigs fed tankage as compared with those fed fish meal would be expected to consume a larger daily ration and make correspondingly larger gains than those recorded. Every pig in both lots made an average daily gain in excess of 1 pound but there were two pigs which made slow gains in lot 1 as compared with only one in lot 2. The average lot gains of the pigs fed soybean oilmeal did not vary materially except that the inclusion of 0.1 percent of choline chloride in ration 4 appeared to make the feed mixture distasteful to the pigs resulting in a smaller feed consumption and slower gains. This apparent lack of palatability of ration 4 was not as noticeable near the close of the experiment as at the beginning.

The depressing effect of choline was noticeable in the average daily feed consumption per pig and consequently in the average daily gain. Dr. M. H. Roepke of the Division of Veterinary Medicine of the University of Minnesota suggested that the effects of choline chloride may be similar to those of acetylcholine which interferes with the normal nerve reflexes in the intestines. Atropine is a drug which might counteract undesirable effects of choline chloride upon the nerves of the intestinal mucosa and hence its use might be beneficial in this condition.

At the conclusion of the experimental feeding period the pigs of lot 4 were continued on the ration containing choline and atropine was given in the drinking water for nine successive days at the rate of .01 of a grain per head. There was a slight decrease in the daily consumption of feed during the time the atropine was administered.

Lot 5 was fed a ration similar to that fed lot 3 except that 0.1 percent of *dl*-methionine was added. Scouring of the pigs started from 5 to 7 days after feeding began and was severe during the course of the experiment. Whether or not the scouring interfered seriously with the gains of the pigs could not be determined as the feed consumption and rate of gains of lot 5 were similar to that of lot 3. After the feeding period was concluded (103 days) the lot 5 pigs were fed the experimental ration previously given to lot 3. After 7 days of feeding on the ration not containing methionine, the pigs had stopped scouring and the feces were normal for a period of 13 days at which time the supply of the ration was exhausted. During this 20 day

period the feed consumption of lot 5 increased over the last 20 days of the experimental period by 36 percent.

A brief investigation was conducted on the probable cause of scouring on the ration containing added methionine. The hypothesis for the study was based on the role that amino compounds may play in stimulating growth of intestinal micro-flora. Methionine in the presence of an otherwise favorable medium may conceivably stimulate production of intestinal flora to an extent that would interfere with normal digestion and elimination. The effectiveness of sulfa-therapy in controlling scours through the reduction of intestinal flora was studied as follows.

At the conclusion of the experiment lot 3 was changed to the ration fed to lot 5 during the feeding period of 103 days. Six days later the pigs began to scour and were treated by oral administration of sulphathaladine at the rate of .75 gram daily per 10 pounds of body weight. At the end of 24 hours, the scouring had stopped and the feces continued to be normal for the following 5 days when the feeding was discontinued because the feed mixture containing methionine was exhausted.

TABLE 3. FEED CONSUMPTION AND GAINS MADE

Items compared	Lot number				
	1	2	3	4	5
No. of pigs per lot	9	9	7	9	9
Av. initial wt. per pig, lb.	50.5	51.2	51.6	49.4	50.7
Av. final weight per pig, lb.	192.4	216.4	197.1	187.3	194.4
Av. daily gain per pig, lb.	1.38	1.60	1.41	1.34	1.40
Av. daily ration per pig, lb.	5.09	5.82	5.50	5.25	5.56
Feeds for 100 pounds gain, lb.	369	363	390	392	395

Summary

Fish meal was a more efficient supplement to corn than tankage or soybean oilmeal. The average daily gain of pigs fed fish meal was considerably higher than the gains when tankage or soybean oilmeal furnished the supplemental protein. The addition of choline to the ration containing soybean oilmeal had a depressing effect upon daily feed consumption and rate of gain. The addition of methionine to the ration containing soybean oilmeal did not alter the average daily gain or feed consumption in spite of severe scouring of the pigs receiving methionine. The interaction of some ingredients of the ration plus methionine caused scouring as indicated by a reversal experiment following the original trial. This scouring may have been caused by a more active intestinal flora for it was arrested by oral administration of sulphathaladine.

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NUTRITIVE REQUIREMENTS OF BREEDING EWES FOR MAINTENANCE, LACTATION AND GROWTH[1]

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IN PREVIOUS experiments (Shrewsbury *et al.*, 1942, 1943), it was found that protein, vitamin A, and factors contained in the press juice of alfalfa constituted some of the main deficiencies of a ration of corn, silage, and oat straw for breeding ewes. Breeding ewes have been maintained in satisfactory condition and have produced healthy, rapidly growing lambs when fed approximately 2.5 pounds of artificially dehydrated alfalfa hay daily with grain and silage. The substitution of artificially dehydrated oat or rye grass for alfalfa has resulted in superior maintenance of the ewes and significantly increased rate of growth of their lambs.

The experiments reported herein include additional observations on the deficiencies of the oat straw basal ration and on the nutritive value of cereal grass fractions.

Two series of experiments are described. One was conducted in 1942–43 and included twelve lots each of 15 two-year old ewes. The second was run in 1943–44 and consisted of five lots each of 10 three-year old ewes and four lots each of 15 three-year old ewes. These ewes were employed in a similar experiment in 1941–42. The ewes were assigned to the various lots by random selection (Shrewsbury *et al.*, 1943) and were fed the rations listed in table 1. All lots were equalized as closely as possible with respect to consumption of protein and energy although the failure of some to consume their feed allotments introduced some deviation from the calculated amounts.

The ewes were weighed at the beginning of the experiment, just before lambing, and at the end of lactation. The lambs were weighed at birth and at eight weeks. Wool clip was obtained on all of the ewes.

The dehydrated cereal grasses, oat straw and fractions of cereal grass were supplied by a commercial laboratory.[4] The first, second, and third cutting alfalfa hays were all harvested in Indiana from the same farm and dehydrated by a local plant.

In order to improve their physical properties the roughages were finely ground through a hammer mill and cane molasses mixed in at a level of 20 percent. Crystalline vitamins were purchased from Merck and Company; all other feeds and supplements were obtained locally.

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[4] The cooperation of the Cerophyl Laboratories, Kansas City, Missouri, in furnishing these materials is gratefully acknowledged. Special thanks are due Dr. W. R. Graham for his interest and suggestions.

TABLE 1. FEED CONSUMPTION OF EWES (AVERAGE DAILY FEED IS IN POUNDS)

INGREDIENT	Lot number																
	1	1A	2	2A	3	4	5	6	7	8	9	10	11	12	13	14	15
Yellow corn	1.75	1.64	.63	.68	1.24	.72	.68	.68	.68	.68	.92	.68	1.22	1.23	.50	.68	.71
Corn silage	1.17	1.0	1.16	1.00	1.13	1.16	1.00	1.00	1.00	1.00	1.00	1.0	1.21	1.13	1.16	1.15	1.17
Rye grass			2.28	2.0	.99												
Oat grass						2.24											
Oat straw	.89	1.00								1.00			.90	1.33			
Water solubles of rye grass										.58		.58					
Residue of rye grass											1.6	1.6					
1st cutting alfalfa hay							2.4										
2nd cutting alfalfa hay								2.4									
3rd cutting alfalfa hay									2.4								
Alfalfa hay															3.28	1.97	2.00
Soybeans																.49	.50
Vitamins													Carotene[1]	Mixture[2]			Mixture[2]
Casein										.50			.50	.50			
Salt	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
Molasses	.22	.25	.57	.5	.20	.51	.5	.5	.5	.25	.40	.40	.23	.33	.00	.00	.00
Steamed bone meal										.10			.04	.04			
Total feed, pounds	4.03	3.92	4.64	4.21	3.56	4.63	4.61	4.61	4.61	4.14	3.95	4.29	4.06	4.52	4.94	4.29	4.38
Daily energy, therms	1.93	1.86	2.04	1.84	1.74	2.06	2.0	2.0	2.0	1.84	1.61	1.93	1.99	2.14	1.78	1.87	1.92
Daily protein, pounds	.24	.22	.70	.66	.37	.48	.42	.57	.54	.54	.58	.58	.57	.60	.47	.51	.52
Year	1943	1944	1943	1944	1943	1943	1944	1944	1944	1944	1944	1944	1943	1943	1943	1943	1943

[1] See text for carotene amount

[2] See text for vitamin mixture amount.

The average daily feed, the total feed, the average daily protein intake and the average daily energy content of the rations are shown in table 1. The protein and energy calculations were based on analyses and values from Morrison's 1938 tables.

In order to overcome the difficulties of comparing the growth weights of single and twin lambs the smaller of each set of twins was removed from the experiment within the first four days after birth.

The data were treated statistically by analysis of variance according to Snedecor (1938).

Results

The results obtained when artificially dehydrated cereal grasses and oat straw were fed are summarized in table 2. The dehydrated rye grass was fed at about 2.25 pounds daily and one pound daily (lots 2 and 3). The dehydrated oat grass was fed at about 2.25 pounds daily (lot 4). The gains of the ewes during pregnancy were much greater when either dehydrated oats or rye grass was fed at the 2.25 pound level than when the dehydrated rye grass was fed at the one pound level, and all three lots gained more than the control lot (No. 1) receiving oat straw. Conversely, the loss in weight of the ewes during the lactation period was small when dehydrated rye or oat grass was fed. Death losses in the ewes and lambs were not appreciably affected by the type or amount of roughage fed. There was no apparent relationship between the roughage fed and the birth weight of the lambs. The wool clip was significantly greater in the lot receiving the high level of dehydrated rye grass (lot 2). The growth rate of the lambs during the first eight weeks was significantly greater in all lots receiving dehydrated cereal grasses. Since it has been previously shown (Shrewsbury *et al.*, 1942) that there is a high correlation ($r=0.89$) between milk production of the ewe and growth of the lamb, it is evident that a basal oat straw ration is not conducive to maximum lactation in sheep.

The effects of feeding 2.4 lbs. of various cuttings of artificially dehydrated alfalfa as compared with oat straw are shown in table 2. The second and third cuttings produced significant increases in rate of gain during pregnancy and in wool clip. In the 1943 experiments more single than twin lambs were born but the reverse was true in 1944. For this reason the statistical analysis was performed on the single lamb birth weights in 1943 and on the twins in 1944. (The data on twin lambs birth weights are not shown in the table.) In all previous experiments in this project analyses have been made on single lambs and no relationship was found between the ration fed and the birth weight of the lambs. However, a significant difference was found in birth weight between lambs from ewes fed second and third cut-

TABLE 2. DATA ON EWES AND LAMBS FED DEHYDRATED GRASSES, 1ST, 2ND AND 3RD CUTTING DEHYDRATED ALFALFA HAY

Lot No.	Ration	Av. gain of ewes during pregnancy	Death losses				Av. birth wt. of single lambs	Av. birth wt. of all lambs[2]	Av. wt. of wool clip ewes	Av. wt. of lambs at 8 weeks	Av. gain of lambs 8 weeks
			Ewes		Lambs						
			Tot. ewes	Tot. deaths	Lambs born[1]	Deaths 1st 8 weeks					
		lbs.					lbs.	lbs.	lbs.	lbs.	lbs.
1943 Experiments											
1	Oat straw, control	16.0	15	0	17	5	9.6	8.4	8.6	31.2	21.6
2	Dehyd. rye grass, 2¼# daily	31.5**	15	2	14	4	9.9	9.2	9.6*	46.2	36.8**
3	Dehyd. rye grass, 1# daily	21.3	15	1	18	1	10.4	9.6	8.9	41.3	31.6**
4	Dehyd. oat grass, 2¼# daily	35.5**	15	2	18	2	9.7	9.0	9.0	46.6	36.9**
1944 Experiments											
1A	Oat straw, control	19.9	10	1	11	1	11.8	9.2	8.5	30.6	20.4
5	1st cutting dehyd. alfalfa hay	25.6	15	2	24	2	11.1	8.8	8.8	32.7	23.1
6	2nd cutting dehyd. alfalfa hay	38.1**	15	0	22	1	11.0	9.9	10.4**	40.1	29.6
7	3rd cutting dehyd. alfalfa hay	38.7**	15	0	27	1	9.6	9.5	10.1**	43.9	34.0

* Significantly different from control lot at 5 percent level of t.

** Significantly different from control lot at 1 percent level of t.

[1] One lamb of twin sets discarded.

[2] Statistical analysis determined on single lambs in 1943 experiments, on twins in 1944 experiments.

ting alfalfa and those fed oat straw. The importance of this finding is questionable. Death losses of ewes and lambs were not related to the ration fed. No significant differences in rate of gain of the lambs were observed. The lambs of the ewes receiving the third cutting of alfalfa grew faster than those in any other lot but the difference in gain from the lambs in the oat straw basal lot was slightly less than the 14.6 pounds required for significance at the 5 percent level. It is likely that if a larger number of lambs had been available for study the difference in gain would have been statistically significant. The lambs in the third cutting alfalfa hay lot (No. 7), the dehydrated cereal grass lot (No. 2A) gained 13.6 and 14.4 pounds more, respectively, than did those in the oat straw lot (No. 1A).

Attempts were made to concentrate the active constituents of the cereal grasses. In previous experiments (Shrewsbury *et al.*, 1943) it was shown that the press juice of alfalfa contained a considerable amount of the potency. This indicated the presence of a water soluble factor. In the present experiments the nutritive properties of the water soluble and the residue fractions of rye grass were tested. The data which are summarized in table 3 show that the water soluble fraction (lot 8) had little or no supplemental value. The residue from the rye grass (lot 9) was about equal to whole rye grass (lot 2A) in the maintenance of ewes during pregnancy and nearly equal to it in producing growth of the lambs. It was superior with respect to wool production. The fractionation process apparently had not caused any destruction of the active constituents since the recombined fractions (lot 10) were comparable to the original rye grass. Accordingly, no conclusions regarding solubility can be drawn at this time.

Another approach was made by adding proteins and vitamins to the basal oat straw ration. Commercial casein was used as the protein and the following vitamins were administered: Carotene 10 milligrams, calcium pantothenate 2 mg., thiamin 2 mg., riboflavin 2 mg., pyridoxine 2 mg., choline 12 mg., niacin 28 mg., ascorbic acid 30 mg., and alpha-tocopherol 2 mg., per head daily. The results of these studies are presented in table 3.

The addition of vitamin A and casein (lot 11) or mixed vitamins and casein (lot 12) to the oat straw ration brought about a definite improvement in its nutritive value. However, the results were not nearly so good as those produced by cereal grass (table 2, lots 2 and 4). Besides the added vitamins and protein, other factors which are present in cereal grass evidently are needed for optimum results with breeding ewes. The identification of these factors must await future work.

In the 1943 experiments (table 3) the field cured alfalfa hay was poor in quality. It produced results only slightly better than did the oat straw ration. However, it was thought that improvement brought about in the

TABLE 3. DATA OF EWES AND LAMBS FED DIFFERENT FRACTIONS OF CEREAL GRASSES, AND ON THE VALUE OF VITAMIN AND PROTEIN ADDITIONS TO THE OAT STRAW AND ALFALFA RATIONS ON EWES AND LAMBS

1944 Experiments

Lot No.	Ration	Av. gain of ewes during pregnancy	Death losses				Av. birth wt. of single lambs	Av. birth wt. of all lambs[2]	Av. wt. of wool clip ewes	Av. wt. of lambs at 8 weeks	Av. gain of lambs 8 weeks
			Ewes		Lambs						
			Tot. ewes	Tot. deaths	Lambs born[1]	Deaths 1st 8 weeks					
		lbs.					lbs.	lbs.	lbs.	lbs.	lbs.
1A	Oat straw control	19.9	10	1	11	1	11.8	9.2	8.5	30.6	20.4
8	Water solubles of rye grass	17.4	10	1	13	0	11.8	9.9	8.1	34.9	24.0
9	Residue of rye grass	35.1**	10	0	18	0	—	8.6	10.6**	41.6	31.9
10	Water solubles and residue of rye grass recombined	34.1**	10	0	17	0	11.5	9.7	9.6*	46.0	35.7*
2A	Rye grass	37.4*	10	0	16	0	9.4	8.6	9.8*	43.8	34.8*

1943 Experiments

1	Oat straw, control	16.0	15	0	17	5	9.6	8.4	8.6	31.2	21.6
11	Oat straw-casein-vitamin A	26.4*	15	3	16	3	10.3	9.1	8.1	37.0	27.2
12	Oat straw-casein-mixed vitamins	21.1	15	3	20	2	9.5	9.2	9.4	38.8	29.5*
13	Field cured alfalfa	17.2	15	1	18	2	8.8	8.3	8.3	37.6	26.3
14	Field cured alfalfa-soybeans	19.7	15	1	19	4	9.3	8.3	8.7	40.7	30.9**
15	Field cured alfalfa-soybeans mixed vitamins	24.2	15	0	17	4	10.4	9.9	8.2	40.6	31.3**

* Significantly different from control lot at 5 percent level of t.

** Significantly different from control lot at 1 percent level of t.

[1] One lamb of twin sets discarded.

[2] Statistical analysis determined on single lambs in 1943 experiments, on twins in 1944 experiments.

performance of the breeding ewes by additions to this poor quality alfalfa hay ration might be of value in determining the factors which are lacking in the oat straw basal ration. The addition of a protein supplement (soybeans) and vitamins to the oat straw ration (table 3, lots 13, 14 and 15) resulted in some improvement over the alfalfa alone, but the response was not nearly equal to that obtained with dehydrated cereal grass.

The data were treated by analysis of multiple regression in an effort to evaluate the effects of the different amounts of protein and energy in the rations. In the case of gains of ewes during pregnancy, 64 percent of the variation between lots was due to multiple regression of gain on protein and energy. With gain of lambs it was 56 percent. Differences in the quality of protein as regards the amounts of essential amino acids probably explains most of the variation. However, significant deviations from multiple regression exist. This indicates that factors other than protein and energy were operative. Since the addition of crystalline vitamins and high quality protein (casein) to the basal oat-straw ration did not bring about results comparable to those produced by dehydrated cereal grasses, it appears that other unknown factors are necessary to supplement oat-straw as a roughage for the optimum performance of breeding ewes. However, since the precise vitamin requirements of sheep have not been determined, it is possible that variations in quantity and in combinations of vitamins might result in further improvement in the results.

Summary

Dehydrated cereal grasses (rye and oats) were found to have a high nutritive value with corn and silage for breeding ewes.

Dehydrated third-cutting alfalfa hay was comparable to dehydrated cereal grass in nutritive value for breeding ewes. First-cutting alfalfa hay was only slightly better than oat straw and the second cutting approached the third cutting alfalfa in nutritive value.

The water soluble fraction of rye grass used in these experiments did not contain the supplementing factors necessary for optimum performance of breeding ewes. The residue after water extraction retained these factors in concentration approximating the original cereal grass.

The addition of protein (casein) and crystalline vitamins to the oat straw ration or a protein supplement (soybeans) and vitamins to a poor quality alfalfa hay ration improved the rations, but did not make them equal in nutritive value to rations containing dehydrated cereal grass.

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HERITABILITY OF TYPE AND CONDITION IN RANGE RAMBOUILLET LAMBS AS EVALUATED BY SCORING

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DIFFERENCES in type (mutton conformation) and condition (degree of fatness) are generally considered to be responsible for differences in the price per pound when range lambs are sold on the market. Since these traits are most evident when the first culling of lambs occurs soon after weaning, it seems probable that they receive considerable emphasis in most sheep breeding enterprises. Despite the evident importance which seems to be attached to these traits, little reliable information concerning them is available.

Estimates of heritability for type and condition as evaluated by scoring are presented in this study. Some knowledge of heritability is useful to the breeder in estimating how rapidly progress can be made in selecting for a trait, in deciding how much emphasis should be given different traits, and in choosing an efficient breeding system.

Data and Methods

The data used in this study were taken in 1941 and 1942 as a routine part of the breeding program of the Western Sheep Breeding Laboratory, Dubois, Idaho. The lambs were born in April and May, herded with their dams on sagebrush-grass range until about July 1, when they were trailed to the high summer range in the Targhee National Forest. Practically no culling took place before weaning in August. Complete records were available for 2183 lambs and for 892 of their dams.

A committee of two or three experienced animal husbandmen working independently scored each lamb for type soon after weaning. Lambs considered as having most satisfactory market type were given a score of 1 and those having least satisfactory type a score of 5. Fifteen scoring units were obtained by assigning plus or minus values to lambs considered as being slightly above or below an exact unit. The average type scores of the committee were used in the analysis. An additional man, by feeling along the back and ribs of each lamb, estimated the degree of fatness and assigned scores for condition. Scores for type and condition were adjusted for environmental factors (sex, age of dam, type of birth and rearing, age at weaning and percent inbreeding) according to the differences found in these same data by Hazel and Terrill (1945).

[1] Western Sheep Breeding Laboratory, Dubois, Idaho.

Some of the lambs born in both 1941 and 1942 were produced in inbred lines and others by top-crossing inbred sires to noninbred ewes. Hence the records were separated according to year of birth and system of mating and analyzed as 4 separate groups. Since inbreeding changes both the half-sib correlation and the intra-sire regression of offspring on dam as compared with those expected in random-bred populations, estimates of heritability were calculated according to the formulas given by Hazel and Terrill (1945a). Whereas in noninbred samples the half-sib correlation is multiplied by 4

TABLE 1. MEAN SQUARES FOR TYPE AND CONDITION SCORES OF 2183 LAMBS

Group	Year	Source of variation	Degrees of freedom	Mean squares for type score	Mean squares for condition score	Constants
One-sire inbred lines	1941	Total	698	0.2313	0.1721	$k = 18.83$
		Between sires	36	.5338*	.2164	$f' = 0.026$
		Within sires	662	.2149	.1696	$f = 0.066$
	1942	Total	909	.2165	.1817	$k = 24.47$
		Between sires	36	.5746**	.3157**	$f' = 0.041$
		Within sires	873	.2017	.1762	$f = 0.076$
Top-crosses	1941	Total	304	.1730	.1956	$k = 9.81$
		Between sires	30	.1979	.2273	$f' = 0.054$
		Within sires	274	.1702	.1922	$f = 0.000$
	1942	Total	268	.3015	.2341	$k = 9.22$
		Between sires	28	.2992	.1367	$f' = 0.053$
		Within sires	240	.3018	.2455	$f = 0.000$

* Signifies probability of chance occurrence $<.05$.
** Signifies probability of chance occurrence $<.01$.

and the intra-sire regression of offspring on dam by 2, these factors must be modified by the inbreeding of the parents (f') and offspring (f) in samples from inbred lines or from top-crosses by inbred sires. The correct factors for the half-sib correlation are $\frac{4}{1+f'+6f}$ and $\frac{4}{1+f'}$, while those for the intra-sire regression are $\frac{2}{1+f'-2f}$ and 2, respectively, for the two latter mating systems. An additional correction, unimportant in the present data, may be necessary for inbred lines at higher levels of inbreeding.

TABLE 2. MEAN SQUARES AND COVARIANCES FOR TYPE AND CONDITION SCORES OF 892 DAMS AND OFFSPRING

Group	Year	Source of variation	Degrees of freedom	Mean squares for type score			Mean squares for condition score			Constants
				Dams	Offspring	Cross-products	Dams	Offspring	Cross-products	
One-sire inbred lines	1941	Total	194	0.3309	0.2349	0.0084	0.3505	0.1931	0.0071	
		Between sires	31	.5964**	.2229	.0654	.4909	.1588	.0085	$f'=0.036$
		Within sires	163	.2803	.2372	−.0024	.3238	.1997	.0069	$f=0.097$
	1942	Total	411	.2724	.2370	.0959	.3022	.1893	.0348	
		Between sires	36	.4329**	.3026	−.0016	.4843*	.3523**	.1324	$f'=0.048$
		Within sires	375	.2570	.2308	.1066	.2847	.1737	.2541	$f=0.101$
Top-crosses	1941	Total	119	.2813	.1637	.0363	.3678	.1443	.0340	
		Between sires	26	.3048	.1745	.0282	.3278	.1198	.0478	$f'=0.054$
		Within sires	93	.2748	.1607	.0387	.3790	.1512	.0301	$f=0.000$
	1942	Total	164	.2218	.2796	−.0402	.2641	.1658	.0040	
		Between sires	28	.2202	.3045	−.1305	.4069*	.1141	.0011	$f'=0.053$
		Within sires	136	.2222	.2744	−.0216	.2347	.1764	.0046	$f=0.000$

* Signifies probability of chance occurrence <.05.
** Signifies probability of chance occurrence <.01.

Results and Discussion

Table 1 shows the analyses of variance for the type and condition scores of the 2183 lambs, while the variance and covariance analyses of the scores for the 892 dams and offspring are given in table 2.

A comparison of the mean squares for between sires with those for within sires in table 1 indicates that there is a marked tendency for lambs by the same sire to receive similar type scores in the inbred lines but not in the top-cross groups. Some inequality in this respect is consistent with the presumed effect of the two mating systems and with the greater number of offspring per sire (k) in the inbred lines. The analysis of the dam's type scores (table 2) shows that the mean squares for between sires are also considerably greater than those for within sires for the inbred lines but not for the

TABLE 3. ESTIMATES OF HERITABILITY AND STANDARD ERRORS FOR TYPE SCORE

Group	Year	Half-sib method		Intra-sire regression method	
		Heritability	Standard error	Heritability	Standard error
One-sire inbred lines	1941	0.208	0.076	−0.020	0.171
	1942	.190	.064	.098	.116
Top-crosses	1941	.062	.117	.282	.156
	1942	−.004	.114	−.194	.180
Average		.152	.042	.068	.074

top-cross groups. This also is consistent with the assortment of related ewes into the inbred lines and with the random assortment of noninbred ewes into the top-cross groups. These differences appear to be somewhat larger than they should be if the inbreeding and the larger number of offspring per sire in the inbred lines were the sole causes.

Estimates of heritability for type score, calculated from table 1 by the half-sib method and from table 2 by the intra-sire regression method, are shown in table 3. Although considerable variation exists between some of the 8 estimates, no two of them differ by more than twice the standard error of their difference. The 4 estimates by the half-sib method average 0.152 and those by the intra-sire regression method 0.068. Although it seems logical that negative estimates are the result of sampling errors, the evidence they provide is as valid as that from the larger positive estimates, which

in turn may be due to positive sampling fluctuations. The weighted average for the two methods, representing the combined information from all the data relative to the heritability of type score, is 0.13 ± 0.04.

Estimates of heritability for condition score, given in table 4, were calculated from the data in tables 1 and 2 in the same manner as those for type score. The estimates made by the intra-sire regression method are higher than those made by the half-sib method, whereas with type score the reverse was true in 3 of the 4 groups. The 8 estimates for condition score range from -0.192 to 0.204 and thus are not quite as variable as those for type score. Although there is only one negative estimate, most of the others are somewhat smaller than those for type score, the weighted average for the heritability of condition score being 0.04 ± 0.03.

TABLE 4. ESTIMATES OF HERITABILITY AND STANDARD ERRORS FOR CONDITION SCORE

Group	Year	Half-sib method		Intra-sire regression method	
		Heritability	Standard error	Heritability	Standard error
One-sire inbred lines	1941	0.041	0.044	0.050	0.146
	1942	.084	.043	.204	.095
Top-crosses	1941	.069	.118	.159	.130
	1942	−.192	.070	.039	.149
Average		.024	.028	.138	.062

The chief findings of this study are that scores for type (mutton conformation) and condition (degree of fatness) are about 13 ± 4 percent and 4 ± 3 percent heritable, respectively, in range Rambouillet lambs. The general applicability of these estimates cannot be ascertained until additional studies are conducted under other conditions. McMahon (1943) gave estimates of 15 and 13 percent, respectively, for the heritability of "breed type" and "fleshing." These traits appear to be generally comparable to the type and condition of the present study. Terrill and Hazel (1943) reported an estimate of 12 percent for the heritability of type score in range Rambouillet yearling ewes. Thus the few studies which have been made are consistent in ranking the heritability of both type and condition low.

Both type and condition can be influenced within wide limits by nutrition and other environmental factors. Mutton conformation in particular is the result of so complex a system of simpler traits which interact with

each other (so far as their ultimate effect upon type of the individual animal is concerned) that no system of linear measurements has yet been devised to replace the animal husbandman's subjective method of comparing animals with a mental standard or ideal and scoring or ranking them accordingly. Because symmetry, particularly balance and style, play an important role in the evaluation of type, extremity in one or two respects may cause a low score in one case and a high score in another. This was pointed out by Stonaker and Lush (1942) in discussing the heritability of conformation in swine. They suggested that selection for conformation was comparable with selection for an intermediate in many visible characteristics, the limitations of which have been studied by Wright (1935).

If heritabilities of type and condition are actually as low in the breed as a whole as they appear to be in the population studied here, phenotypic selection alone will be almost impotent in promoting an appreciable rate of genetic improvement. The heritability of type, and particularly of condition, is so low that progeny testing will lead to a more rapid (but still very slow) rate of improvement than phenotypic selection (Dickerson and Hazel, 1944). Progress would be more rapid if most of the total culling done for type and condition were deferred until progeny test information were available. This would leave greater latitude in culling on individual performance for the more highly hereditary traits, where the information is more truly representative of actual breeding value than it is for type and condition. The effectiveness of the program probably could be increased by recurrent inbreeding and outcrossing (Lush, 1943).

Since the ultimate purpose of all livestock breeding is to attain the maximum rate of improvement in general economic efficiency, the emphasis given each trait in selecting breeding animals should depend upon its economic importance as well as upon its heritability. The present study contains no information on the value of type and condition in reflecting price per pound when lambs are marketed. Winters (1944) reported that quality of lambs, presumably including type and condition, was the least important of several factors in influencing economic returns per ewe. Hazel and Terrill (1945a) found that the heritability of weaning weight and staple length was about 30 and 40 percent, respectively. Since type and condition appear to rank low in both relative economic importance and heritability, much of the emphasis given them in selecting breeding animals might more wisely be directed toward the improvement of growth rate, wool production, and lamb production of ewes.

Because of the wide divergence in type and fleshing ability among the various breeds of sheep, it was thought that these traits might be highly hereditary. While isolation by breeds, inbreeding, and persistent selections

might be expected to gradually reduce intra-breed genetic diversity, this reduction should have been more rapid in breeds developed primarily for mutton production than in those where the major emphasis was given wool production. Studies now under way on the recently developed dual purpose breeds of sheep may provide an answer to some of these questions.

Summary

Estimates of the heritability of type (mutton conformation) and condition (degree of fatness) were made from the half-sib correlations and intra-sire regressions of offspring on dam from data on 2183 range lambs and 892 dam-offspring pairs.

The average of 8 estimates indicated that the heritability of type was about 13 ± 4 percent, while that for condition was about 4 ± 3 percent.

The best methods of selecting and breeding for traits with such low heritability are discussed. Because other traits are more highly heritable and more important for total production in sheep, it seems that type and condition should receive relatively less emphasis, than is given in present practice, in a sound breeding program directed toward the improvement of sheep.

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HERITABILITY OF GROWTH AND EFFICIENCY IN BEEF CATTLE

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THE relative importance of heredity in determining performance in economic characteristics has been reported in swine (Lush, 1936; Whatley, 1942; Hazel *et al.*, 1943; Nordskog *et al.*, 1944; Baker *et al.*, 1943), in sheep (Terrill and Hazel, 1943) and in dairy cattle (Lush, 1940). No comparable studies have been reported on beef cattle, which may be explained by the limited amount of data available on this type of livestock. During the past several years, performance data on beef cattle have accumulated at the U. S. Range Livestock Experiment Station, Miles City, Montana. It is the purpose of this paper to present a preliminary study of estimates of heritability of variations in weights, gains and efficiency of feed utilization, as determined from these data.

Source of Data

All animals used in these studies were produced at the U. S. Range Livestock Experiment Station, under projects conducted cooperatively between the Bureau of Animal Industry and the Montana Agricultural Experiment Station. All calves were dropped on the range during an approximately 8 weeks period in April and May each year. The calves were weaned each year about the 20th of October and placed on feed in individual feeding stalls. The steers were all full fed on a grain mixture of 6 parts of corn, 3 parts of beet pulp, 1 part of wheat bran, 1 part of linseed meal and ½ part of alfalfa leaf meal. The steers received good grade alfalfa hay as roughage. The method of feeding and the feeds of the bull calves changed from year to year as shown in table 1. In 1938–39 the corn was to be fed ad libitum to the bull calves but considerable bloat was experienced and the corn was held down to alleviate this condition. The gains in 1938–39 were far below the later years owing to this limited feeding.

During the breeding season each bull was bred to 25 to 30 random selected cows either as yearlings or as two-year-olds. Eight steer calves from

[1] The authors are Animal Husbandman, Bureau of Animal Industry and Associate Professor, Montana Agricultural Experiment Station, respectively. They wish to express their appreciation to Dr. G. E. Dickerson, Animal Geneticist at the Regional Swine Breeding Laboratory for his helpful assistance in suggesting methods for analyzing these data, and to A. L. Baker and J. R. Queensberry, Associate Animal Husbandman and Senior Animal Husbandman, respectively, U. S. Range Livestock Experiment Station, under whose direction the data were collected.

TABLE 1. FEEDS AND METHOD OF FEEDING OF BULL CALVES FROM 1938 TO 1941 AT THE U. S. RANGE LIVESTOCK EXPERIMENT STATION

Year	Concentrates or concentrate mixture	Hay	Rate of feed per day	
			Concentrates	Hay
1938–39	Corn and beet pulp	Alfalfa	Corn ad lib. Beet pulp 2 lbs.	5 lbs.
1939–40	½ corn, ½ beet pulp	Alfalfa	Mixture ad lib.	5 lbs.
1940–41	6 parts corn 3 parts beet pulp 1 part wheat bran 1 part linseed oil meal ½ part alfalfa leaf meal	Alfalfa	Ad lib.	Ad lib.
1941–42	Same as 1940–41	Alfalfa	1½ percent body weight	Ad lib.

each sire, if available, were selected at random from each sire's calf crop and were fed out on record-of-performance trials. Each year all steer calves were fed out for the same period of time. The lengths of feeding periods were: 1940–41, 265 days; 1941–42, 252 days; 1942–43, 273 days; and 1943–44, 259 days. In all, 177 steers were fed. They were sired by 23 bulls. A total of 47 bulls were fed from 1938 to 1941 out of which the 23 bulls were selected as prospective sires. The average weights and gains of the bulls and steers used in this study are shown in table 2.

TABLE 2. AVERAGE WEIGHTS AND GAINS IN POUNDS OF BULLS AND STEERS FOR EACH FEEDING YEAR

Year	Number of animals	Class of animals	Average birth weight	Average weaning weight	Average final weight	Average daily gain on feed
1938–39	4	Bulls	84	409	756	1.45
1939–40	18	Bulls	85	436	847	1.84
1940–41	12	Bulls	83	424	790	1.86
1941–42	13	Bulls	78	420	731	1.59
1940–41	24	Steers	78	404	875	1.78
1941–42	62	Steers	82	415	919	2.00
1942–43	45	Steers	83	402	923	1.94
1943–44	46	Steers	79	391	851	1.80

Data and Discussion

Two methods were used to estimate heritability. These were, (1) half-

sib correlations obtained by analysis of variance, and (2) regressions of progeny average on sire obtained from covariance analysis.

Heritability Determined by Half-Sib Correlations

Analysis of variance described by Snedecor (1937) was used to determine the significance of differences between sire groups (table 3). Sire differences were not significant for birth weight and weaning weight but were highly

TABLE 3. INTRA-YEAR ANALYSIS OF VARIANCE OF WEIGHTS AND GAINS OF STEERS—(MEAN SQUARES ONLY)

Source of variance	Degrees of freedom	Mean squares					Theoretical composition
		Birth weight	Weaning weight[1]	Final weight	Total gain	Efficiency of gain[2]	
Between sire groups within years	19	100	1917	13,983**	8,860**	2504.05**	$A+kB^3$
Within sire groups within years	154	68	1539	4,487	2,499	901.44	A

[1] Corrected for age at weaning.
[2] k is equal to the average number of progeny per sire group—7.696.
[3] Efficiency of gain is the gain per 100 pounds of total digestible nutrients consumed.
** P is less than .01.

significant for final feed lot weight and gain in the feed lot. Variances were further analyzed into their theoretical components using the method described by Winsor and Clarke (1940). The theoretical composition of the mean squares is also shown in table 3. In an infinite population, the sum of $A+B$ is the total or population variance. The fraction $B/(A+B)$ is the correlation between half-sibs and when multiplied by 4 represents the theoretical additive genetic portion of the total variance or heritability. The results

TABLE 4. THEORETICAL VALUES OF VARIANCES AND HERITABILITY OF WEIGHTS AT THREE AGES AND GAIN IN THE FEED LOT

Index	A	B	$A+B$	Heritability 100 h
Birth weight	67.79	4.12	71.91	23
Corrected weaning weight	1539.16	49.13	1588.29	12
Final weight	4486.73	1233.94	5720.67	81
Gain in feed lot	2498.53	826.65	3325.18	99
Efficiency of gain	901.44	208.13	1109.57	75

(table 4) indicate that variations in birth weight are slightly more highly heritable than variations in weaning weight but neither are as highly heritable as variations in final feed lot weight and rate or efficiency of gain in the feed lot. The general trend of these estimates is in general agreement with those reported for swine by Nordskog *et al.*, (1944). However, the estimate of heritability for final weight, gain in the feed lot and efficiency of gain is 2 to 4 times as high as similar measures of growth reported in swine.

Heritability Determined by Sire-Offspring Regression

The second method is based on the regression of the average performance of the progeny on the performance of the sires. Only 20 sires were available for this study due to purchase of bulls or to lack of data on the bulls during comparable periods. The following equation was used to determine heritability from the sire:offspring regression:

$$h = 2b_{o:s}\sqrt{\frac{T_s}{T_0}}$$

Where $b_{o:s}$ is the regression coefficient of offspring average on sire, T_s is the actual total variance of the entire unselected group of sires, and T_o is the total variance of the individual steer offspring.

The regression coefficients (b) obtained from these data were as follows:

Birth weight	$b_{o:s} = .179 \pm .090$
Weaning weight	$b_{o:s} = -.057 \pm .092$
Final weight	$b_{o:s} = .352 \pm .209$
Daily gain on feed	$b_{o:s} = .236 \pm .138$
Efficiency of gain	$b_{o:s} = .223 \pm .150$

Heritabilities as determined by this method for the measures of growth and efficiency were as follows:

Birth weight	42 percent
Weaning weight	0 "
Final weight	69 "
Daily gain on feed	46 "
Efficiency of gain	54 "

Since as shown in table 1, the sires were fed differently during each of the feeding years, it was thought advisable also to study the sire:offspring regression within groups of sires fed the same year. This would correct for level of feeding for the sires but would not eliminate the yearly effects in the offspring. This correction was made by an analysis of covariance. The regression co-efficients were:

Birth weight	$b_{o:s} = .149 \pm .085$
Weaning weight	$b_{o:s} = .178 \pm .100$
Final weight	$b_{o:s} = .585 \pm .283$
Daily gain on feed	$b_{o:s} = .627 \pm .095$
Effieiency of gain	$b_{o:s} = .200 \pm .084$

Heritabilities were as follows:

Birth weight	34 percent
Weaning weight	30 "
Final weight	94 "
Daily gain cn feed	97 "
Efficiency of gain	48 "

These latter figures on heritability agree more closely with those obtained from the half-sib correlations.

Interpretation of Results

Three methods of analysis gave the following estimates of heritability of measures of growth and efficiency:

	Birth weight	Weaning weight	Final weight	Gain	Efficiency of gain
Inter-year correlation between half-sibs	23	12	81	99	75
Regression of progeny average on sire total variance	42	0	69	46	54
Regression of progeny average on sire within year of sire	34	30	94	97	48

The lowest values except for weaning weight are much higher than those shown for swine by most of the research workers in that field. Because the figures on heritability of feed lot gain and final weight were higher than the writers considered should be reasonably expected, data from other sources at this and other stations where the Bureau of Animal Industry is conducting record of performance experiments with beef cattle were analyzed and heritability estimated by the half-sib correlation method. Weights of heifers at 18 months of age at Miles City indicate 61 percent heritability, even though they were on the range except for the winter-feeding period. Daily gains of steers on record of performance at Beltsville, Maryland, and Tifton, Georgia, indicate heritability in excess of 100 percent. Results reported by Guilbert and Gregory (1944) though limited to four related sires indicated differences large enough to have approximately 40 percent heritability.

In view of the consistency of these results from all stations, there should be some explanation for the high heritability obtained in this analysis. Some of the assumptions underlying the validity of this type of analysis

may not have been fulfilled but a discussion of some of these assumptions as related to this particular population may aid in evaluating the results of this study.

The mating system may have deviated from a true random population and by chance one sire had a better group of cows than another sire. The system of selecting the cows has been to randomize by age groups. Each animal on the Range Station has a number assigned in numerical sequence in order of birth. A card is made out for each cow when she is old enough to breed, and the cows are assigned to breeding herds by placing the cards into the number of piles to correspond to each breeding herd. This gives each bull approximately an equal number of each age group of cows and the breeding, weight, condition, or production of each cow are not considered.

Line differences have not been taken into account in this analysis; but as is shown in table 5, when differences between lines are considered, the half-sib correlation is 0.26 which would indicate heritability in excess of 100 percent. The analysis of variance shows that the mean squares between lines were not significantly different from the mean squares of sires within lines. Therefore, it is concluded that line differences were not a factor in determining the high estimates of heritability.

The most probable cause of the high heritability estimates is that the population is too restricted to give reliable estimates. However, it is possible to estimate the sampling error of these heritability estimates.[2] The lower fiducial limits of final weight, gains and efficiency would be as follows:

	Heritability	Lower fiducial limits	
	100 h	P—.10	P—.02
Final weight	81	40	25
Gains	99	51	33
Efficiency	75	31	17

It is apparent that these estimates are subject to large sampling errors, but in spite of this fact, the lower fiducial limits suggest these characters

[2] The significance of a mean square is obtained by dividing it by its appropriate error mean square. The resulting ratio is F. In terms of mean square components $F = \frac{(A+kB)}{A}$ which is equal to $(1+K\frac{B}{A})$. B is therefore equal to $\frac{\frac{(F-1)A}{(F-1)A}}{K}$ for an n and n' degrees of freedom. Since H is equal to $\frac{4B}{A+B}$ and substituting $\frac{(F-1)A}{K}$ for B in the equation, the following equation expresses the sampling error of $H = O$, $E'_h = \frac{4(F-1)}{K+F-1}$. In order to calculate chance deviations from true heritability (H is greater than zero) it is necessary to employ Fisher's z for which the upper and lower limits may be obtained for a given level of probability. By converting the fiducial limits of z in terms of F and substituting into the formula: $\frac{4(F-1)}{K+F-1}$ we obtain the fiducial limits of H.

to be subject to a substantial amount of heritable variation. The large values for the upper fiducial limits illustrate the possibility of obtaining estimates over 100 percent (due to sampling error) even though true heritability can never exceed this amount.

Environmental differences, other than those accounted for by years, between sire groups may account for some of the measurable differences between sire groups. The steers from each sire group were fed in pens next to each other and it could be possible for the feeder unconsciously to favor

TABLE 5. ANALYSIS OF VARIANCE OF GAINS IN THE FEED LOT WHEN DIFFERENCES BETWEEN LINES ARE CONSIDERED

Source of variance	Degrees of freedom	Mean square	Half-sib correlation
Between years	3	37390	
Between lines within years	6	7969	
Between sires within lines and years	13	9272	.260
Within sire groups	154	2499	

or disfavor certain groups. This would account for a larger half-sib correlation than should exist where this environment is not a factor but it can hardly account for the large values of the heritability determined by the regression of sire on offspring.

The sires have also shown their ability to repeat their progeny test when mated to their own relatives. It has been the practice at Miles City to test a sire again when bred to relatives; i.e., half-sisters and first cousins. The close agreement of the sires tested so far is shown in table 6, although

TABLE 6. AVERAGE DAILY GAINS OF 6 TO 8 STEER OFFSPRING FROM SIRES MATED TO THE TEST HERD COWS (RANDOM SELECTED) AND THEN BRED TO RELATIVES FOR LINE HERD TESTS

Sire number	Average daily gain of steers from:	
	Test herd cows	Line herd cows
15	1.79 lbs.	1.69 lbs.
16	1.80	1.78
17	1.75	1.68
22	2.07	1.94
28	2.09	2.02

in every case the inbred calves made slightly lower daily gains than the outbred calves.

It is believed that the estimates of heritability derived in this study are

too high, probably due to the relatively small size of the population analyzed. However, it is concluded that heredity plays an important part in the differences in gains that occur among beef calves. In fact it appears that the influence of heredity on gaining ability and also on efficiency of feed utilization by calves may be high enough to make selection, based on individual performance for these traits, effective without the use of progeny testing. Further study of similar data is needed, however, to establish these points with certainty. At the U. S. Range Station, it is planned at least for the present to continue the progeny test in order that more data may become available for studies of this nature.

Summary

A study was made of the records from 177 steer calves from 23 sires at the U. S. Range Livestock Experiment Station, Miles City, Montana, to estimate the relative effect of heredity on weights, gains and efficiency of gain. Two methods were used, namely: The intra-sire correlation obtained by analysis of variance, and the sire:progeny regression obtained by covariance analysis.

Heritabilities obtained from intra-sire correlations for the various weights and gain were: birth weight 23 percent; weaning weight 12 percent; final feed lot weight 81 percent; gain in the feed lot 99 percent and efficiency of gain 75 percent. Heritabilities obtained from sire:progeny regression were: birth weight 42 percent; weaning weight 0 percent; final weight 69 percent; daily gain 46 percent; and efficiency of gain 54 percent. When adjustments were made for differences in feeding for the sires each year, the heritability was found to be 34 percent for birth weight, 30 percent for weaning weight, 94 percent for final weight, 97 percent for daily gain and 48 percent for efficiency of gain.

The estimates of heritability obtained from these data are higher than seems reasonable and the cause or causes of these high estimates are not known. Meanwhile, these results are interpreted to indicate that the breeder and feeder of beef cattle can take encouragement from this report with respect to selection of cattle for both rate of gain and efficiency of feed utilization.

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A NEW METHOD FOR THE CONTROL OF CATTLE TICKS IN TROPICAL REGIONS

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Introduction

A NEW control method for the cattle tick in tropical regions is necessary for the eradication of this foremost cattle pest. Established control measures, such as the use of cattle dipping vats charged with arsenical solutions, have never been popular in the Tropics. The dipping of cattle has proved expensive in many instances due to losses sustained from overheating, a lowered milk production following dipping, mechanical abortions, arsenical poisoning, and injuries suffered by animals forced through the dips.

Squibb (1945) published results of experiments in which the cattle fever tick, *Boophilus microplus* (Canestrini, 1887; Dönitz, 1907) was controlled by a spray formula consisting of a solution containing rotenone and DDT (dichlorodiphenyltrichloroethane). Results of these experiments indicated a possible new method for the eradication of the cattle fever tick in tropical regions. It was therefore decided to continue these experiments by field tests and to revise the formula if necessary, to make it more specific for tick control.

Regardless of whether cattle in the tropics have an immunity to tick fever and regardless of the future possibility of breeding animals resistant to the fever, most workers agree that the complete eradication of the cattle fever tick not only saves the cattle industry considerable money but also makes possible more rapid breed improvement programs. Cattle imported into the Tropics to improve the existing breeds often suffer as high as 95 percent mortality due to tick fever or piroplasmosis. Mohler (1932), referring to tick eradication and breed improvement programs in the United States, says that, "Purebred Northern Cattle could then be brought into the South to improve the native stock, without the danger of death from tick fever, and the total cost of tick extermination will be far less than the amount saved in the first year after it has been accomplished."

Deaths resulting from tick fever are only a part of the losses sustained by cattlemen because of ticks. As an ectoparasite, ticks can cause severe anaemia and irritation leading to "tick worry." With a heavy infestation

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of these blood sucking parasites, the normal functions of the skin are impaired and resulting wounds are susceptible to secondary infections and possible worm infestations. These ill-effects from the tick have a direct effect upon milk production, growth and the physical well being of cattle. That the tick can be controlled and eradicated has been demonstrated by the results of an extensive and sustained campaign in the southern and southwestern portions of the United States. As described by MacKellar (1942), these formerly heavily infested areas have been freed of the cattle fever tick, so that now less than 1 percent of the cattle in the area are ticky.

The cattle tick is still a problem of tropical regions, for a number of reasons. There is a lack of sufficient cattle dipping vats, enforced quarantine, dipping regulations, and practically little or no control over ticks on cattle in transit. There is also the difficulty of convincing cattlemen accustomed to cattle ticks, of the economic significance of these pests. Only "all out" control measures will succeed in eradicating this serious cattle pest. Furthermore there are certain tropical conditions that interfere with efficient control and regulation measures such as an abundance of wild animals and extensive swamps, and areas without adequate means of transportation and communication. MacKellar (1942) states that the ability of the tick to perpetuate itself on wild deer in Florida has greatly complicated and delayed the completion of tick eradication in more of the large swampy areas.

There are many methods now being practiced in Costa Rica for the control of the cattle tick. Dairy cattle, oxen and fattening animals are hand-bathed with weak arsenical or concentrated salt solutions. Larger operators supplement these practices with dipping in vats, but these are relatively few in proportion to the cattle population. For example, the Department of Liberia, the beef cattle center of Costa Rica, has one vat per each 14,000 head of cattle, and the animals are so distributed over the area that many animals have to be driven 24 hours under tropical conditions to arrive at the dipping vat.

Cattle dipping vats are not popular in Costa Rica because cattlemen consider them too expensive. The expense is not so much in the construction cost of the vat but rather in operational expenses. Observation shows that cattle driven any distance under tropical conditions lose considerable weight. Animals, with hoofs softened due to excessive humidity and water, or those having to cross through rocky volcanic terrain, are subject to injuries during the drives often becoming lame. Dipped animals must usually be rested before being returned to the pastures to avoid losses from overheating. Oxen must often be rested a week, in some areas, before being

worked. It is not uncommon to find a 20 percent reduction in milk production for the week following the dipping of dairy cows. Many of the difficulties encountered with the dipping of cattle such as mechanical abortions, poisonings, deaths from injuries, can be traced directly to the lack of experienced personnel and improperly designed cattle vats.

Experimental Procedure

The experimental work reported in this paper was divided into two parts, (1), the development of a formula which would be specific against the cattle tick and would avert the use of a dipping vat, and (2), field tests of the

Figure 1. Ticks on a cow's udder. This infestation is considered medium, the cow having 1 to 3 ticks per square inch of body surface.

established formula. It was recognized that field tests cannot approach the accuracy of laboratory controlled tests, and that estimations of tick populations and mortalities, due to the solutions used, was subject to error. Therefore, in order to make the results as significant as was possible, only

heavily infested animals, those averaging more than 2 ticks per square inch of body surface were used in the tests. Likewise in order to determine climatic influences on the spray method, tropical dry and wet lowland areas, noted for year around heavy infestation of cattle ticks, were selected for conducting the field tests.

Method of Estimating the Tick Population of the Animals

The greatest concentration of ticks infesting the animals was usually found between the hind legs and on the neck. A cardboard disk, which had three 1-inch squares cut out, was used for making the estimate of the number of ticks per square inch of body surface. This disk was placed on at least three different parts of the animal's body of the lowest and greatest visible concentration of ticks, a count of the ticks within the cut out squares was then made and the average taken. This system gave a rough estimate of the tick population of the animal.

Spray Technique Used in the Experiments

A small flit gun that held 120 c.c. of solution was used throughout the trials. Each animal was sprayed over lightly beginning at the head and working toward the rear quarters. Folds between the legs and around udders were carefully sprayed last. Eighty to 150 c.c. of the solution were found to be sufficient to cover an animal. At no time, in any of the trials, was more than 150 c.c. of the spray solution used. The spray covered the animal so finely that after a few minutes it was difficult to determine which was or was not a sprayed animal.

Results

Formula for Cattle Ticks

After a considerable number of tests, a new combined solution was derived from the formula 107 previously described by Squibb (1945). The previously described formula contained DDT and rotenone mixed together in solution, whereas in the new combined solution, these two ingredients are separated into two parts, A and B, and the two combined are more specific against the cattle tick than either one used separately. Part B of the combined solution was mixed prior to use. This change was made because of the poor keeping qualities of rotenone. Babcock and Curling (1942), advise that in the use of rotenone in dips, it is well to use the solution within six days after its preparation or re-charge the dip with additional rotenone because it breaks down in the course of time.

The two solutions A and B,[3] referred to above, are as follows:

[3] The combined solution (1 part solution A to 1 part solution B) is recorded under the Institute formula number I.A.S./ah 9-110.

A		B	
DDT	— 6.16 gms.	Green crushed derris roots	— 22.5 gms.
Kerosene	—66.6 c.c.	Water	—200 c.c.
Water	—33.3 c.c.	Neutral soap	— 3.0 gms.
Neutral soap	— 1.8 gms.		

The materials are prepared in the following manner: (A)—The DDT was dissolved in the kerosene in the proportions given above, and the solution was slightly warmed. The water and the neutral soap were mixed and then brought to 98° C. This near boiling solution was then well mixed with the slightly warm DDT kerosene solution. Upon cooling, this mixture forms a thick, milky solution. Warming and vigorously agitating the solution will return it to its original condition, if it separates. (B), Green crushed derris roots, with an average rotenone content of 5 percent (dry basis), were used as the source of the rotenone. The rotenone content of the roots was extracted in water for 24 hours, and the resulting extract filtered. The neutral soap was dissolved in hot water then cooled and added to the rotenone solution.

Solution A can be mixed in any size quantities and stored, because of its excellent keeping qualities. Solution B should be prepared just prior to use. Derris or Cube powder could be substituted for the green crushed derris roots, as a source of rotenone. In the following part of the paper the combined solution referred to is mixed, 1 part solution A to 1 part solution B; any variations are so indicated.

Six heavily tick infested animals were divided into 3 groups of 2 animals each and treated as follows: *Group 1*. Each animal was sprayed with 100 c.c. of the combined solution. At the end of 7 days an average of 93 percent tick mortality was effected. *Group 2*. Each animal was sprayed with a mixture of 50 c.c. of solution A plus 50 c.c. water. This was for the purpose of testing the effect of the DDT alone. At the end of seven days approximately an 85 percent mortality of the ticks was effected. *Group 3*. Each animal was sprayed with a mixture 50 c.c. of solution B plus 50 c.c. water, for the purpose of testing the effect of the rotenone alone. At the end of 7 days, approximately a 35 percent mortality of the ticks was effected.

Results of Field Tests

This part of the experimental work consisted of testing the solution in the field. It was desired to test the solution in two distinct tropical lowland climates, namely an extremely wet area and an extremely dry area. It was fortunate that in Costa Rica these two distinct climates occur in the same months and are only two hours apart by air transportation.

One group of experiments were made on the "Huete" hacienda, which is located in the Turrialba Valley, and is representative of excessively

humid and wet conditions. On December 21, 1944, 36 head of oxen, which averaged 3 to 8 ticks per square inch of body surface, were sprayed with the combined solution. Rainfall started approximately 4 hours after the spray was applied, and continued for 8 successive hours. Throughout the entire experiment of 71 days, the oxen remained in the same pastures, without shelter. Cattle in adjacent pastures, not treated for the destruction of ticks, were kept as controls. Seventy-two hours after the application of the treatment the oxen were practically free of ticks; 96 hours after the application an average mortality better than 92 percent was effected. The sprayed animals were examined weekly for reinfestation. On January 24, 1945, reinfestation was observed as beginning, and on March 2, 1945, at the end of 71 days, six of the 36 animals were reinfested to approximately their original tick population. The other 30 head carried approximately $\frac{1}{3}$ their original infestation. All the new infestation consisted of seed ticks, not more than 6 adult ticks being found on all 36 animals. The controls in adjacent pastures remained heavily infested throughout the experiment.

On March 2, the six heavily reinfested oxen were sprayed again, this time using a variation of the combined solution; 2 parts of solution A were mixed to 1 part of solution B; this increased the DDT content of the solution. Observations made over a seven-day period did not show that the increased DDT percentage was superior to that of the combined solution; the tick mortality was approximately 92 percent.

Other experiments were conducted in Guanacaste, Costa Rica, on the haciendas "La Chacra" and "La Cueva." The Guanacaste area is probably one of the most heavily tick-infested areas in Costa Rica. At the time of the trials this area was representative of dry lowland tropical conditions, because a six months dry season was then in progress.

One test took place on the hacienda "La Chacra." Thirty head of heavily infested animals, having 6 to 20 ticks per square inch of body surface, were selected for the trials. The entire 30 head were kept together in the same pastures throughout the trials. Twenty of the thirty animals were dipped in a standard arsenical solution and freed of their ticks. The other 10 head were sprayed with 80 to 150 c.c. of the combined solution per head, and examined at 24 hour intervals. At the end of 48 hours the large ticks had disappeared; however the largest percentage of the small ticks still appeared alive. At the end of 120 hours all the small ticks had either dropped off or were still attached to the animal withered and dead. A 94 percent mortality of the ticks had been effected.

On February 1, after a period of 15 days, all 30 head were compared as to tick infestation. Those animals that had been freed of their ticks by the use of the standard arsenical solution were again heavily infested, while the

10 head that had been sprayed with the combined solution carried less than 10 percent of the infestation of the dipped group. On February 7, after a period of 22 days, the sprayed group had not yet attained 35 percent of their former infestation.

Another test took place on the hacienda "La Cueva" which is located adjacent to "La Chacra." On February 2, 1945, 10 head of dairy cows, with approximately 2 to 4 ticks per square inch of body surface, were selected. As it was desired to again test a variation of the proportions of the combined solution, each of the 10 cows were sprayed with approximately 100 c.c. of 1 part solution A to 2 parts solution B. For a control 15 heavily infested animals on the "La Chacra," hacienda were sprayed, each animal receiving from 80 to 150 c.c. of the combined solution. On February 9, after a period of 7 days, the controls of the hacienda "La Chacra" and the 10 dairy cows were compared as to the tick mortalities. The mortality of the ticks on the cows receiving 1 part solution A to 2 parts solution B was visibly not as good as on the 15 head used as controls and sprayed with the combined solution. This again confirmed all previous results obtained by the use of this combination.

Discussion of Results of Various Field Tests

A new combined solution (one part solution A to one part solution B) was devised. From the results of several tests this solution was found to show excellent possibilities for use as a spray in the control of cattle ticks.

Throughout all the tests observations were made as to a possible poisonous or continued irritable effect of the combined solution on sprayed animals. The majority of the animals would lick themselves following a spray application, and over a six month period with the combined solution having been sprayed on more than 1000 animals, no poisonous or continued irritable effects of the solution were observed.

The apparent progressive killing characteristics of the combined solution offer a possibility for the destruction of a great number of seed ticks that might seek a sprayed host during the period the spray remains effective.

It is interesting to note that in connection with the Guanacaste, Costa Rican field tests the tremendous number of ticks in the fields would infest the workers. Twenty cubic centimeters of the combined solution lightly sprayed over the trousers would prevent this infestation. Accompanying workers not so sprayed would return heavily infested. Upon spraying the ticks on the trousers of these infested workers, the ticks would be destroyed. This would indicate that the combined solution is immediately effective on ticks that are not attached to flesh.

Recommended Procedures

From the results of the experiments and field tests as to the working effects of the solution, it would be recommended for a general eradication campaign of any tick infested area, to spray each animal with 80 to 150 c.c. per head of the combined solution, every 14 days. The combined solution may be used with the same results diluted: 1 part of the combined solution to 1 part water, if desired. Observations showed a fine penetrating spray to be the most efficient, and that the percentage of the tick mortality was definitely related to the spray technic. Excessive use of the combined solution, namely more than 150 c.c. applied per animal, was found to be a waste of material.

Because the combined solution apparently kills ticks for as long as seven days, a sustained program of spraying should control ticks in tropical areas in less time than was necessary with previous control methods.

The solution could be applied on the animals by a number of methods. Small owners can make efficient use of hand or knapsack sprayers, while larger operators could use power sprayers or possibly a tunnel or chute arrangement in which cattle could be driven through a fine, penetrating mist. This equipment could be dismounted after use and transported to other parts of the farm, thus averting long cattle drives.

Summary

A new combined solution was devised that showed excellent possibilities for use as a spray in the control and possible eradication of the cattle tick in tropical areas. The spray method averts the use of dipping vats, poisonous solutions, and long cattle drives. It is economical and practical to apply, averting the danger of losses from overheating, mechanical injuries and poisonings. With the cooperation of the cattlemen in tropical regions the spray method using the combined solution, which apparently kills ticks over a period of seven days, can be more rapid at effecting complete eradication than the control methods now being employed in the tropics.

Tests indicated a DDT-rotenone combination superior to the use of either ingredient alone, and that increasing the percentage of DDT in the combined solution did not increase the mortality percentage of the ticks. There were indications that a reduced percentage of DDT in the combined solution was not as efficient.

The combined solution worked equally well under dry and wet tropical lowland conditions and that a continuous rainfall of 8 hours following applications of the spray in one group of field tests did not interfere with obtaining an average of 93 percent mortality of the animals' ticks.

Observations recorded over a six month period on 1000 sprayed animals indicated no poisonous or continued irritable effects from the use of the solution.

Eighty to 150 c.c. of the combined solution was found to be sufficient to cover an animal and effect a 85 to 99 percent mortality of ticks within 7 days after the spray's application. Observations showed a fine penetrating spray to be the most efficient and that the mortality percentage was definitely related to the spray technique.

An apparent progressive killing action of the combined solution was observed to last as long as 7 days. The mortality of ticks effected was as follows: 24 to 48 hours after the spray application, 20 to 55 percent; 48 to 96 hours, 55 to 85 percent; 96 to 168 hours, 85 to 99 percent.

Twenty cubic centimeters of the combined solution sprayed over trousers of men working in heavily tick infested pastures prevented their infestation.

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CHEMICAL COMPOSITION AND DIGESTIBILITY OF FLAT PEA FORAGE IN THREE STAGES OF MATURITY[1]

T. W. Daniel, F. B. Wolberg, V. L. Miller, J. H. Alswager, M. E. Ensminger, and A. A. Spielman
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Introduction

THERE are large acreages of logged-off land in Western Washington which have not been devoted to any agricultural use. Most of these areas are rather hilly and unsuited to cultivation but would lend themselves to pasture if they could be made to yield a fair crop of forage with a high nutritive value. To the present time, no pasture crops have been found which can compete with the bracken fern and underbrush or which will not dry up in midsummer on hilly land. Flat pea (*Lathryus sylvestris wagneri*) is a perennial legume that shows promise of fulfilling the need for such a forage plant.

Flat pea is a deep-rooted perennial legume that was introduced from Germany about 1890. The plant can be identified by the slender, wing-margined, weak and reclining stems, with long, narrow, paired leaflets (ratio length to width about 5 or 6 to 1) forming a sharp V. The flowers are pink and in loose racemes of 3 to 10 blossoms. A plant may have flower buds and mature seed at the same time.

The early tests and reports on flat pea were inadequate but generally unfavorable, so the forage was at first discarded as unpromising. A few of the early seedings in Western Washington have survived in spite of competition with ferns and brush and in recent years have re-awakened an interest in their forage value. Recent seedings and plantings have shown their ability to compete with ferns and brush on hill lands and to produce a large volume of forage over a wide range of soil conditions.

Flat pea starts making rapid growth the middle of May and continues growth until late summer. On good sites with heavy growth, the forage stays green until heavy frosts kill it; but on very droughty soils the stands

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are sparser and after the seed pods have matured, usually in August, the forage slowly turns yellow. Cattle have grazed the forage with excellent results, but they do not accept the new forage very readily until they have become accustomed to grazing it.

The length of time required to grow a good stand of flat pea was a major factor in its early loss of favor. On good soils, an excellent yield is now possible in the second year if the seed is properly treated and sown heavily enough and at the right time, and if the young stand is kept free from excessive competition the first year. The development of flat pea stands is very slow on areas where a native cover of ferns and brush is already established. Where the native cover is not too dense, a fair stand will probably develop in four to five years when a good establishment of flat pea seedlings has been obtained. The large yields of forage under favorable conditions indicate that it may be used for a hay crop and analyses suggest that it could be used as a protein supplement.

The potential importance of this new forage has made it desirable to study the seasonal changes of its composition and digestibility. The data presented in this study were obtained from a series of six digestion trials with sheep. Three stages of growth of the flat pea were fed green. In three other trials the dried material of the same three growth stages from the same plantings was fed.

Review of Literature

Considerable experimental work in various states was done on flat pea previous to 1900, but no further work was then done until the possibilities of the plant as a cutover land forage crop awakened interest in it at the Western Washington Experiment Station in the 1930's. The chemical analyses made during these investigations show that this forage is usually superior to alfalfa leaves on the basis of the percentage of nutrients it contains. Analyses of the flat pea on a dry-matter basis have been reported by a number of workers (Goessmann, 1897; Grunder, 1941; Hills, 1895; Jaffa, 1893; Kedzie, 1893; Smythe, 1892; Sweetser, 1897; Wickson, 1892; and Woods, 1895), and average composition based on figures given in these reports is presented below together with the average composition of alfalfa leaves as given by Morrison (1941):

Component	Flat Pea	Alfalfa leaves
Ash	7.3	11.47
Crude protein	24.0	24.6
Crude fiber	31.0	15.86
Crude fat	3.4	3.37
N-free extract	34.6	44.7

Previous to the digestibility trials by Hodgson and Knott (1936), the digestibility of flat pea was assumed to be comparable to that of similar forages. Hodgson and Knott's work indicated that the forage was palatable and highly digestible.

Procedure

The forage used in this experiment was obtained from a pure stand of flat pea which was seeded approximately 40 years ago on hilly logged-off clay soil at Ashford, Washington. The slope on which it grew faced a little south of east; therefore, the forage was not exposed to the full force of the summer radiation and as a result the forage retained a high moisture content until late in the season. In addition, there were only a few times when rains and heavy dews did not influence the moisture content. It was often necessary to collect material during rain storms.

Six digestion trials were conducted with sheep. Four sheep were used in each of the three trials in which green flat pea was fed. Three stages of maturity were studied; the immature or pre-bloom stage, the early bloom stage, and the late bloom stage. Seed pods had not formed in the early bloom stage but occasional pods were nearly filled in the late bloom stage. The last three trials were conducted with material which had been cut at the same time as the material used in the green feed trials but had been dried artificially at low temperature (65°–78° Centigrade). Only three sheep were used in each of the trials with flat pea hay.

The sheep were placed on a ration of green flat pea about two weeks before the start of the initial digestion trial and were also fed flat pea between trials. The flat pea fed between trials had a small percentage of grass in it but only pure flat pea was used during the actual feeding trials. The initial trial was begun on June 6, 1943, and the final trial on the green forage ended on August 31. The last trial with the dried flat pea ended on November 28, 1943. The green forage was cut each day or occasionally every other day and weighed for the afternoon and morning feeds. The flat pea constituted the entire ration, and sheep were fed all they would eat. Each day one sample was taken for dry matter determinations and for chemical analysis of crude protein, crude fiber, ether extract, nitrogen free extract, calcium and phosphorus. The chemical analyses of the feed and feces were made according to the methods as outlined by the Association of Official Agricultural Chemists (1940), except for calcium and phosphorus which were made according to the method of Gerritz (1935).

Experimental Results

The percentage composition of the flat pea forages used in the digestion trials is shown in table 1. In the fresh green forage, the protein content

dropped from 37.76 percent in the early stage of maturity to 28.11 percent in the full bloom stage. The crude fiber increased from 23.46 percent to 29.00 percent, the nitrogen free extract increased from 27.49 to 33.36 percent. There was also a slight increase in the calcium content and a pronounced decrease in phosphorus with the advance in maturity. The dried forage showed approximately the same decrease as indicated by a protein content of 35.31 percent for the early stage and 24.39 percent for the full bloom stage.

TABLE 1. CHEMICAL COMPOSITION OF FLAT PEA FORAGE USED IN THE DIGESTION TRIALS (DRY MATTER BASIS)

Trial No. and type of forage	Crude protein	Crude fiber	Ether extract	N-Free extract	Ash	Calcium	Phosphorus
	percent	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*
Trial I Flat pea, early stage, green	37.76	23.56	3.78	27.49	7.41	0.450	0.539
Trial II Flat pea, early bloom stage, green	34.18	27.59	4.70	26.63	6.95	0.460	0.524
Trial III Flat pea, late bloom stage, green	28.11	29.00	3.62	33.36	5.91	0.567	0.347
Trial IV Artificially dried flat pea, early stage	35.31	21.51	3.63	32.01	7.54	0.572	0.561
Trial V Artificially dried flat pea, early bloom stage	30.99	29.09	3.80	29.34	6.78	0.497	0.449
Trial VI Artificially dried flat pea, late bloom stage	24.39	30.44	4.58	33.73	6.86	0.668	0.297

The average moisture contents for the three green feed trials were 11.2, 14.3, and 18.0 for trials I, II, III respectively. There was a maximum variation in dry matter content of the material fed of 6.0 percent in the first trial, 8.9 percent in the second trial and 7.5 percent in the third trial. The variations did not appear to have any effect upon the appetites of the animals. The average amount of dry matter consumed increased with each trial because the dry matter content was lower than estimated, especially in the first trial when the amount of surface moisture was appreciable. The increased amount of dry matter shows up in corresponding changes in body weight of the experimental animals from a loss of an average of 3.8 pounds in trial 1 to a gain of 2.7 pounds in trial 3 (table 2).

TABLE 2. DIGESTION COEFFICIENTS, DIGESTIBLE CRUDE PROTEIN AND TOTAL DIGESTIBLE NUTRIENTS OF FLAT PEA (DRY MATTER BASIS) WITH DRY MATTER CONSUMED AND BODY WEIGHTS OF EXPERIMENTAL ANIMALS

Type of forage	Average consumption per animal	Number of sheep	Body weights			Dry matter	Crude protein	Crude fiber	Ether extract	N-free extract	Ash	Digestible crude protein	Total digestible nutrients
			Initial	Final	Change								
Fresh Material													
	grams		lbs.	lbs.	lbs.	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*
Early stage (pre-bloom)	5460.2	4	92.0	88.2	−3.8	76.3	90.2	57.6	64.6	79.0	61.1	34.26	74.94
Early bloom stage	6325.1	4	89.1	88.0	−1.1	69.1	88.4	46.5	66.7	70.6	56.1	30.17	68.86
Seed stage (late bloom)	7899.4	4	87.5	90.2	−2.7	66.2	86.5	42.5	64.0	70.7	61.3	24.32	65.44
Artificially dried material													
Early stage (pre-bloom)	6281.2	3	94.7	90.7	−4.0	74.8	87.0	55.9	63.5	79.8	56.5	30.72	73.47
Early bloom stage	6286.0	3	92.2	93.1	− .9	66.4	87.4	46.9	63.0	66.2	56.9	27.09	65.54
Seed stage (late bloom)	6241.4	3	93.1	92.9	− .2	63.5	82.5	42.7	63.4	69.1	61.4	20.12	62.96

The dry matter content of the artificially dried flat pea hay was quite uniform (averaged 86.2 percent) for the three trials and the amount of dry matter consumed was likewise very uniform. The greater loss in body weight in trial 4 as compared with trials 5 and 6 can be explained as a possible result of reduced water intake when the animals were abruptly changed from a succulent green forage to hay. The sheep were also reluctant to eat all their ration the first day or two after the change. The animals varied in the eagerness with which they ate the forage although it was usually very palatable.

A summary of digestion coefficients for all the trials and the digestible crude protein and total digestible nutrient content of the material fed are are shown in table 2. The digestible crude protein content decreased ten percent from the early stage to the late bloom stage in both the fresh and dried materials and also decreased about the same in total digestible nutrient content. The fresh material in the early stage contained 34.26 percent digestible protein which is about equal to linseed meal and therefore possesses possibilities as a protein supplement. The fresh material is only four percent higher in digestible protein and less than three percent higher in total digestible nutrients than the dried material indicating that the drying at low temperatures did not have much influence upon the nutritive value.

The dried forage of the late bloom stage is comparable to the stage of growth of the forage used in the feeding trials conducted by Hodgson and Knott (1936). A comparison of their data with the data presented in table 2 reveals that their results were conservative.

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Experience indicates that the young growth of the forage is readily accepted by cattle and sheep, and field grazing trials have not shown any losses under such grazing. Thus, in a separate preliminary trial, seven yearling sheep were full fed on fresh green flat pea forage as the sole diet with no detrimental effects upon the animals.

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apparent digestibility of flat pea (*Lathyrus sylvestris wagneri*) forage at three stages of maturity when used as fresh green feed and as an artificially dried hay.

The fresh and artificially dried materials were palatable and highly nutritious. Several losses of sheep during the first weeks of feeding indicate that caution should be used in feeding this forage until more comprehensive trials can be conducted to determine its possible toxicity.

The fresh green forage contained on an average 29.6 percent digestible protein and 69.8 percent total digestible nutrients as compared with 26.0 percent and 67.3 percent, respectively, for the artificially dried forage.

The fresh green flat pea in the early stage of maturity (pre-bloom) contained 34.26 percent digestible protein, the early bloom 30.17 percent, and in the late bloom 24.32 percent digestible protein. The total digestible nutrient content for the three stages of maturity was 74.94 percent, 68.86 percent, and 65.44 percent, respectively.

The artificially dried flat pea had digestible protein contents of 30.72, 27.09 and 20.12 and a total digestible nutrient content of 73.47, 65.54 and 62.96, respectively for the three stages of maturity.

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INDEX TO THE PROCEEDINGS OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

Foreword

THE AMERICAN SOCIETY OF ANIMAL PRODUCTION was organized in 1908 under the name American Society of Animal Nutrition. The present name was adopted at the annual meeting in 1912 and was used on the Proceedings beginning in 1913. Beginning with the account of the organization meeting in 1908, Proceedings were published for each year through 1940. In three cases Proceedings for two or three years were published under one cover. These were 1915–16, 1917–18–19, and 1925–26.

In 1940 the Society decided to replace the annual Proceedings with a quarterly publication, the JOURNAL OF ANIMAL SCIENCE. The JOURNAL first appeared in 1942, hence the Society issued no publication in 1941, but abstracts of papers presented at the meetings in 1941 appeared in volume 1, number 1 of the JOURNAL.

The Proceedings contain much useful information, but owing to lack of adequate indexing in the Proceedings themselves, and in indexing journals and libraries, their usefulness has been limited. This index was prepared so that animal husbandry workers and students might have more ready access to the valuable contents of the Proceedings.

The preparation of an index in a form most useful to workers and students was beset with certain difficulties. An author index is simple enough. But a subject index of material as varied as that contained in the Proceedings presents a serious problem. In addition to a wide variety of subject matter, many titles simply defy adequate indexing and others do not indicate the nature and scope of the papers. After considerable "trial and error" it became apparent that the usual subject index alone would not serve satisfactorily, and a listing of titles under subject headings and subheadings was decided upon. It is recognized that this system does not have the advantages of cross-reference of the usual index, but after careful study it appeared to be the most useful single system for cataloging this material, in the subject index.

Each paper or author listed in the index is referred to by year and initial page, thus: **15**:112, indicating the year 1915 and page 112. In every case, the year indicates the year in which the meetings were held, regardless of when the Proceedings were printed.

Each paper is listed only once, in the subject index, and under the heading that appears most suitable. Obviously, no two people would classify all the titles in exactly the same manner.

For convenience in using the subject index, the following outline is presented.

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Workers will need to familiarize themselves with the general arrangement of the subject index, as outlined above, if they are to use it most effectively. By using this reference outline, it should be possible to locate rather quickly the papers on a subject in which one is interested.—Ralph W. Phillips.

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AMERICAN SOCIETY OF ANIMAL PRODUCTION
MINUTES FOR 1945

Officers and Chairmen of Committees for 1946

In accordance with an announcement in the JOURNAL OF ANIMAL SCIENCE, vol. 4, page 462, the officers of 1945 will serve again in 1946. They are:

President: A. D. Weber
Vice-President: W. A. Craft
Secretary-Treasurer: W. G. Kammlade

The chairmen of standing and special committees for 1946 are as follows:

Committee on Investigation.....L. M. Winters (Minnesota)
Committee on Instruction.....R. F. Cox (Kansas)
Committee on Extension.....L. A. Richardson (Tennessee)
Committee on Membership.....W. A. Craft (U.S.D.A., Ames, Iowa)
Special Committee on Information..R. C. Pollock, (Nat'l Livestock and Meat Board, Chicago)
Special Committee on Cooperative Meat Investigations.....
.....J. M. Ramsbottom (Swift and Company, Chicago)
Special Committee on Pasture and Range Investigations.....M. L. Baker (Nebraska)
Special Committee on Evaluation of Feeds.....E. W. Crampton (Macdonald College, Quebec)
Special Committee on Necrology.....W. E. Carroll (Illinois)
Representative on the Inter-Association Council.....W. V. Lambert (U.S.D.A.)
Representative on National Research Council.....H. W. Marston (U.S.D.A.)

Sectional Chairmen for 1946 Meetings

The sectional chairmen appointed for the meetings that were not held in 1945 have been asked to serve in 1946. They are as follows:

Animal Breeding.....R. E. Comstock, North Carolina (Rio Piedras, Puerto Rico, after May 15, 1946)
Beef Cattle.....C. W. Hickman, Idaho
Dairy Cattle.....J. H. Hilton, North Carolina
Extension.....L. A. Richardson, Tennessee
Horses and Mules....Wayne Dinsmore, Horse and Mule Ass'n of America, Chicago, Illinois
Meats.....B. W. Gardner, Jr., Subsistence Research and Development Laboratory, Chicago Quartermaster Depot, Chicago, Illinois
Nutrition.....J. L. Krider, Illinois
Pasture and Range...Marvel Baker, Nebraska
Sheep and Wool.....J. E. Nordby, U.S.D.A., Dubois, Idaho
Swine.....H. G. Zavoral, Minnesota
Teaching.....R. F. Cox, Kansas

Report of the Secretary-Treasurer

This report covers the period November 1, 1944 through October 31, 1945. Both W. V. Lambert and the undersigned served as treasurer during portions of that time, but this report covers the entire year.

Receipts

Balance November 1, 1944	$3,992.00	
Membership dues	2,231.20	
Subscriptions, JOURNAL OF ANIMAL SCIENCE	1,025.55	
Sale of back volumes	213.36	
Sale of Proceedings	90.25	
Reprints, overrun, et cetera	874.90	
Miscellaneous	353.14	
Total receipts		$8,780.40

Expenditures

Office: postage, stationery, et cetera	$ 179.43	
Office: clerical help	20.25	
Expense of Secretary W. V. Lambert to 1944 Annual Mtg.	35.79	
Morrison Hotel, luncheon, et cetera	357.52	
George Banta Publishing Company, JOURNAL OF ANIMAL SCIENCE	2,514.50	
George Banta Publishing Company, Reprints	609.23	
Inter-Association Council	26.50	
Miscellaneous	34.48	
Total expenditures		$3,777.70
Balance on hand		$5,002.70
War Savings Bonds, Series F (current value)		2,035.80
Total assets		$7,038.50

The Society had 640 members on October 31, 1945.

W. G. KAMMLADE

Report of Editor of Journal of Animal Science

The total number of manuscripts submitted through December 31, 1945, was 223. These had been handled as follows:

Published in volumes 1 to 4	180
In press for February, 1946	11
Ready for printer or being edited	12
Refused publication or withdrawn	20
Total	223

A sizeable backlog of manuscripts had accumulated early in the year but favorable paper and financial situations made it possible to publish these,

so that at the end of 1945, publication was as nearly up to date as it could be with a quarterly publication.

When the Editorial Board of the JOURNAL OF ANIMAL SCIENCE was established, it was arranged that two members would retire and be replaced by new men each year. All members of the original board have now completed their terms. The American Society of Animal Production is deeply indebted to the semen who served during the years the JOURNAL was being established. The original members of the Board were W. E. Carroll (Illinois), H. H. Cole (California), J. A. Hill (Wyoming), W. E. Krauss (Ohio), W. J. Loeffel (Nebraska), C. D. Lowe (U.S.D.A.), J. L. Lush (Iowa) and W. E. Petersen (Minnesota). All members other than those on the original board are appointed for four-year terms and this system of rotation will be continued. The two appointments which became effective on January 1, 1946 were L. E. Casida (Wisconsin) and J. F. Wilson (California), representing the physiology and wool fields, respectively.

RALPH W. PHILLIPS

MEMORIALS

M. G. SNELL

Dr. M. G. Snell, Associate Professor of Animal Industry and Associate Animal Husbandman at Louisiana State University since 1928 has been reported missing following the torpedoing of a Japanese prison ship in Philippine waters December 15, 1944. Dr. Snell was born in Lampasas, Texas, November 11, 1900, received his Bachelor's degree at Texas Agricultural and Mechanical College in 1921, a Master's degree from the University of Missouri in 1922, and the degree of Doctor of Philosophy from Iowa State College in 1928. He was the author of a number of experiment station bulletins and many other scientific articles. He was chairman of the Animal Husbandry Section of Southern Agricultural Workers, 1940–41, an active member of the American Society of Animal Production and a member of the Society's Committee on Investigation. At the time of his induction he was national secretary of the Block and Bridle Club. Dr. Snell entered the military service in February, 1941, was commissioned as major while in the Philippines, shortly before the attack on Pearl Harbor, and was made a prisoner by the Japanese at the fall of Corregidor. An officer liberated when the Philippines were retaken reported that Dr. Snell had been in very good health and had been last seen on December 14, 1944.

A. H. WALKER

Dr. Arthur H. Walker, lieutenant colonel, was killed while on active duty in the front lines in Italy on February 10, 1945. He was on leave from his position as assistant professor of animal husbandry at the University of Arizona. Dr. Walker was born in 1900 on a farm in Muskingam County, Ohio, and managed his home farm from 1918 to 1924. He then attended Ohio State University and received the B.S. degree in 1929. In 1930 he returned to Ohio State University as an assistant in animal husbandry. In 1931 he transferred to the University of Wisconsin as a graduate assistant, and received the Ph.D. degree in 1936. He then went to Montana State College as assistant animal husbandman in the experiment station. He was appointed assistant professor at the University of Arizona in 1937, where he engaged in both teaching and research. His research work dealt primarily with nutritional deficiencies of Arizona range forages. He took military leave on July 5, 1941, entering the service as a captain. He was advanced to the rank of lieutenant colonel on January 11, 1944. He was a member of

Sigma Xi, Phi Kappa Phi, and the American Society of Animal Production. Dr. Walker's high attainments in teaching, research and military service are equaled by a sincere devotion to his family. He is survived by his wife, Ina, and three children, Eleanor, Evelyn and Richard, who will continue to live in Tucson.

E. J. THOMPSON

E. J. Thompson, formerly professor of animal husbandry at North Dakota Agricultural College, died following a heart attack on March 28, 1945. Mr. Thompson was born on April 1, 1886 near Egypt, Illinois. He was graduated from the University of Illinois in 1910 and went to North Dakota Agricultural College where he served as instructor in animal husbandry from 1910 to 1930. He was head of the animal husbandry department at the same institution, from 1930 until December 1, 1940, when he resigned to become manager of Tyrconnel Farms Frederick, Maryland. While in North Dakota, Mr. Thompson was secretary of the stallion registration board for 25 years, was active in various State livestock associations and assisted in the formation of the Saddle and Sirloin Club at North Dakota Agricultural College. He was married in 1914 to Ethel Peterson of Fargo, North Dakota, and is survived by her and two sons, Mark and Vance.

M. R. BAKER

Montee Robert Baker was born at Syracuse, Kansas, December 20, 1920, the eldest son of Marvel L. and Florence (Wortham) Baker. He was awarded a Regent's Scholarship and entered the University of Nebraska in 1936. Although largely dependent upon his earnings he made an outstanding record and received the B.S. degree with high distinction in 1940. He was elected to membership in Sigma Xi, Alpha Zeta, Gamma Sigma Delta and Phi Lambda Upsilon. He then enrolled for work in animal genetics at Kansas State College and was awarded the Master's Degree in 1942. He had enlisted in the Air Corps before receiving his degree and was commissioned as a lieutenant on November 10, 1942. For a time Lt. Baker was stationed in Newfoundland and other East Coast points, protecting sea lines against submarines. He was then assigned to the 489th Heavy Bombardment Group and went overseas in May, 1944. As training and operations officer he might have avoided actual combat to a considerable extent, but was perfectly willing to share dangers. On June 25, 1944, his unit participated in a bombing mission on Maintenon, France, His B-24 crashed and he was later reported killed in action as of that date. He is survived by his parents, a brother John, and two sisters, Dorothy and Frances. Although young in years, Montee Baker gave promise of becoming an outstanding teacher and research worker in the animal sciences.

NEWS AND NOTES

Professor and Mrs. F. B. Morrison, of Cornell University, have offered funds to the American Society of Animal Production to provide annual awards for a period of five years, to members of the Society, who have done outstanding recent research of direct importance in livestock production. The award each year will consist of a cash award of $1,000 and a gold medal or other suitable permanent form of recognition. Professor Morrison states that they may wish to continue the awards beyond a five-year period, if conditions are suitable. The Executive Committee has accepted this generous offer, on behalf of the Society, and will establish procedures for making the awards.

A Conference on Fertility was held in New York City on February 1 and 2, under the auspices of the National Committee on Maternal Health. The following members of the American Society of Animal Production participated in the program: S. A. Asdell (Cornell University), R. W. Phillips (United States Department of Agriculture), A. H. Frank (United States Department of Agriculture), L. E. Casida (University of Wisconsin), H. H. Cole (University of California), G. W. Salisbury (Cornell University), V. R. Berliner (Fowlerville, Michigan), John Hammond (Cambridge University), and J. W. Bartlett (Rutgers University). Proceedings of the conference will be available in published form at a later date.

George M. Rommel, who for 20 years was with the United States Department of Agriculture, as the first chief of its animal husbandry division, and more recently with the Tennessee Valley Authority, died on November 26, 1945.

Daniel Thomas Gray, recently dean and dircetor of the University of Arkansas College of Agriculture and Experiment Station, died on October 16, 1945. He was a member of the American Society of Animal Production from 1908 to 1921.

In a news item in the November issue it was stated that C. M. Kincaid had returend to the Virginia Polytechnic Institute after receiving a Ph.D. degree. This was an error and Mr. Kincaid has requested that it be corrected. The correct information is that Mr. Kincaid recently resigned from his position with the Regional Swine Breeding Laboratory and the Iowa Agricultural Experiment Station to become Associate Animal Husbandman with the Virginia Agricultural Experiment Station. During the period January, 1943 to September, 1945 he devoted part of his time to graduate study at the Iowa State College, but did not receive a degree from that institution.

Henry H. Levick (Lt. Col.) has returned, after four years of military service, to his duties as head of the animal husbandry department at Mississippi State College.

John W. Cole, recently discharged from the U. S. Navy, has been appointed assistant professor in animal husbandry at South Dakota State College. He will be in charge of the work with meat.

Lyle S. Hoyt, recently discharged from the U. S. Army, has been appointed as instructor in animal husbandry at South Dakota State College.

W. B. Young has been appointed dean of the College of Agriculture and director of extension at the University of Connecticut.

Jack Turner, Texas cattle breeder, and a graduate of the Texas A & M College, has been chosen to succeed B. M. Anderson, deceased, as secretary of the American Hereford Association.

John Ashton of the Rural sociology department, Texas A & M College, will be relieved of teaching duties at the end of current semester in order that he may devote his entire time to writing a history of the livestock industry of the southwest.

J. H. McLeod, who formerly did animal husbandry extension work in Texas, Arkansas and Tennessee, has been made vice-director of the Tennessee Agriculture Extension Service.

A. K. Mackey, one time member of the animal husbandry staff, Texas A & M College, is now director of agricultural relations at the Oklahoma National Stock Yards Company, Oklahoma City, Oklahoma.

Sni-a-Bar Farms at Grain Valley, Missouri, where long-time experimental work was conducted with beef cattle by cooperation of the Missouri Agricultural Experiment Station and the United States Department of Agriculture, was recently sold to Ralph L. Smith, Kansas City industrialist and stockman.

Don W. Chittenden, formerly eastern field representative of the American Hereford Journal, has resigned to become field secretary of the American Polled Hereford Breeders' Association.

John M. Fargo (Lt. Col.), formerly assistant professor of animal husbandry at the University of Wisconsin, is executive officer at Camp Grant, Illinois, after service in the Pacific theater with the 20th AAF.

Myron D. Lacy, who has been agricultural agent in Clinton County, Iowa, was appointed to the extension animal husbandry staff at Cornell University, effective February 1.

E. E. Grissom has returned from military service to take up his former activities as assistant extension animal husbandman at Mississippi State College.

Frank C. Armer has resigned from the staff of the University of Arizona.

Sedgley D. Nelson was appointed to the staff of the California Extension Service as an animal husbandry specialist, effective November 1, 1945.

L. A. Stoddart, former head of the department of range management at the Utah State Agricultural College, accepted a similar position at the Texas A & M College, effective January 1, 1946.

Charles J. Bell (Lt. Col.) has returned from military service, to resume work in extension animal husbandry at the University of Georgia.

Raymond D. French was made assistant extension animal husbandman at the University of Illinois, effective November 1, 1945.

F. C. Francis, who entered military service in 1943, returned to his position with the Department of Animal Husbandry, University of Illinois, effective October 16, 1945.

Kenneth C. Fouts, former county agricultural agent in the Nebraska Extension Service, has succeeded E. W. Janike, resigned, as assistant extension animal husbandman.

Richard M. McWilliams, former county agent in Clayton County, Iowa, was made assistant extension animal husbandman at Iowa State College, effective February 1, 1946.

George W. Gibson, formerly farm manager for R. C. Roebling, Savannah, Georgia, and later doing agricultural work for commercial interests has returned from military service and has been made extension animal husbandman for the Georgia Extension Service with headquarters at Tifton.

Frederick Wilson, former county agricultural agent at Spearfish, South Dakota, has been made assistant extension animal husbandman at South Dakota State College.

E. M. Harsch, secretary of the Hampshire Swine Registry, died quite suddenly on January 11, 1946.

J. C. Shaw, formerly associate professor of dairy industry at the University of Connecticut, recently became professor of dairy husbandry at the University of Maryland, where he will conduct research in the nutrition and physiology of dairy cattle.

R. E. Comstock of North Carolina State College has accepted a position as head of the animal husbandry department of the Puerto Rico Agricultural Experiment Station at Rio Piedras, effective May 15.